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[625 .142.4]

Some considerations of an economic nature on the use of reinforced concrete sleepers[1],

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Figs. 1 to 4, p. 819.

If reinforced concrete sleepers have not yet reached the desired state of perfection, they have undoubtedly got beyond the purely experimental stage and are now being used on a large scale by different Administrations, particularly in Europe.

It will therefore be not inopportune to examine rather closely the limits of the economic advantages of their use as compared with wooden sleepers. This investigation seems to us, moreover, to be the more desirable because, in our opinion, which as will be seen later on is sufficiently well justified, the maximum dimensions and in consequence the maximum cost of reinforced concrete sleepers are being almost attained if in fact they have not been already.

In another note which has also appeared in the columns of this *Bulletin* [2], we spoke at some length on reinforced concrete sleepers from the technical and constructional points of view.

To-day we will put forward some simple considerations of an economic nature in which we endeavour to put an approximate value upon the limits within which they can be used. As far as possible we shall avoid making any exact evaluations of prices and costs as these are, of necessity, too widely variable not only from one country to another, but even from one locality to another; we will endeavour in other terms to give our argument the most general character. At the end, only as an example, we will give a numerical evaluation.

Naturally, in view of the character of this investigation, we do not pretend, and this moreover would not be possible, to arrive at results of a very close approximation; they will be rather figures of a purely indicative character.

When we speak in what follows of reinforced concrete sleepers and their pro-

(1) Translated from the Italian.

(2) Concrete sleepers, *Bulletin of the Railway Congress*, February 1929.

bable life, we are naturally taking into consideration sleepers already in existence or that have been designed, in which the question of their actual strength and their ability to support traffic and dynamic stresses has been solved, and which in consequence are only subject to ageing and to wear. In other words, we presume that the possibility of the body of the sleeper or of its essential parts breaking, can be ignored except as the result of accident or really exceptional causes or of defects of construction which can be well determined.

This hypothesis does not appear to us to be very far from the truth for any type of sleeper considered, at the present time.

The supposition must however be made, as it would be absurd to consider the use on a large scale of any kind of sleeper which did not give, as regards strength, complete safety, or at least the maximum of guarantees.

2. — If we write :

T = the cost of a sleeper laid in the track,

l = the cost of renewal of a sleeper,

t = the value of a sleeper when withdrawn from the line, the total cost involved in the renewal of a sleeper will obviously be

$$C = T + l - t \qquad (1)$$

It should be noted that in the costs l of labour we have taken into account the whole of the costs occurred in removing the track, taking up and carrying away the worn out sleeper, the substitution of the new sleeper, packing, refastening, etc. On the other hand we have not included the cost of any subsequent screening of the ballast, those of its renewal nor of its loading onto wagons, nor the substitution later on of the sole plates, coach screws, and metal parts in general. Actually these last operations although they are often carried out when sleepers are being renewed only affect to a minimum degree their life, and have to be done and at regular intervals even if the life of the sleeper be infinite.

If we take r = the rate of interest,
n = the life of the sleeper,

the annuity (calculated at the end of each year) equivalent to the present value of the sleeper renewed is from the usual formula

$$\alpha = C \frac{r(1+r)^n}{(1+r)^n - 1} \qquad (2)$$

The annuity arrived at in this way shows consequently the annual cost of each sleeper in service.

This figure being known it seems to us that it would be interesting to see to what extent it takes into account the whole of the elements depending either upon the quality of the materials, or upon the conditions of the line, the intensity of traffic, etc.

For the types of sleeper now in use for a long time (wood or metal) it is easy to solve this question seeing that all the terms of the equations (1) and (2) can be determined with sufficiently close approximation from the statistics of the previous years. The only term upon which there may be differences of opinion is the term r which depends not only upon the rates paid for money, but upon the particular conditions and the financial and administrative policy of the undertaking concerned.

As we have said, the value of α which we will call *the sleeper-year cost* depends not only on the quality of the materials and their price, but also upon the characteristics of the line, the cost of labour, etc... Consequently there is, for each line

and even for each section of line, a corresponding value of the *sleeper-year cost.*

As our subsequent arguments are based upon this *sleeper-year cost* it will be as well to make its significance quite clear.

The value of α does not represent an actual accountancy expenditure incurred chargeable to the costs of operation : it also includes the interest charges on the capital invested.

If α be used as a basis of comparison between two types of sleeper, the maintenance costs of the line have to be divided into two categories: the first, the value of which depends upon the life and the cost of the sleepers, and the second, the value of which is on the contrary independent both of the cost and of the life. In this second category are included all expenditure in connection with the renewing and remaking of the ballast, the straightening and levelling of the line, and the repair and replacement of metal parts, etc. Although this work is often done when renewing the sleepers, it does not depend upon the life of the sleepers other than to a very limited extent and the same thing is true of the varying nature of the work relatively to the type of sleeper used.

It should be noted that we are here speaking of concrete sleepers which technically are entirely satisfactory, and which have in consequence a bearing surface and a transversal stability exactly as good as with the wooden sleeper. As regards improvements in these points, that may be obtained by substituting concrete sleepers for wooden ones, practical use and observation of the types so far used do not allow us to expect that they will be so marked as to affect materially the economic cost based upon the life and the cost of renewal.

There are types of reinforced concrete sleeper with which less ballast is needed, others which make it possible to effect savings in the superstructure (for example the suppression of the metal sole plates) ; these savings can easily be taken into account by deducting their total value (usually small) from the cost of the reinforced concrete sleeper, or by adding it to the cost of the wooden sleeper according as it is possible to estimate the relative life as being nearer to the former or to the latter.

3. — If we now would compare from the economic point of view two types of sleeper for use in the same line we can calculate the relative *sleeper-year costs* and compare them. By distinguishing the terms relating to the wood sleepers by the index (1) and those relating to the concrete by (2), the two types, of course when in the same line, can be said to be economically equal when :

$$\alpha_1 = \alpha_2$$

and consequently :

$$C_1 \frac{r(1+r)^{n_1}}{(1+r)^{n_1}-1} = C_2 \frac{r(1+r)^{n_2}}{(1+r)^{n_2}-1} \qquad (3)$$

In order to abstract values of the expenditure, let us designate by β *the ratio between the cost of renewal of a concrete sleeper and the cost of renewal of a wooden sleeper* : that is we make

$$\beta = \frac{C_2}{C_1} \qquad (4)$$

Equation (3) will then give :

$$\beta = \frac{(1+r)^{n_1}}{(1+r)^{n_1}-1} \cdot \frac{(1+r)^{n_2}-1}{(1+r)^{n_2}} \qquad (5)$$

In equation (5) r and n are known : for each value of n_2 we can ascertain the corresponding value of β.

When we take $n_2 = \infty$, or in other

words when in the extreme case the life of the concrete sleeper is taken as infinite, equation (5) becomes

$$\beta = \frac{(1+r)^{n_1}}{(1+r)^{n_1}-1} \qquad (6)$$

In solving (6) for the different values of n, and of r, that is to say in short for the different values of α, we get the maximum theoretical values of the costs of renewal of the sleepers above which the new type is no longer usable even if its life be supposed to be infinite. We have calculated these values for lifes of n_1 varying from 8 to 20 years and for values of r of 0.5, 0.6, 0.7, and 0.8, and have used them for the diagrams 1, 2, 3, and 4, each diagram being for one value of r.

The values of β so obtained are entirely theoretical, whether because the life of the concrete sleeper is obviously not infinite, or because there are a number of reasons unnecessary to enumerate which prevent the calculations of costs being based on a life of the track if not infinite, at least very long in practice.

In all events the curves of $n_1 = \infty$ whilst being simply theoretical have a certain interest as they show that the margin of expenditure available for the improvement of sleepers is not, even in theory, any too large, especially for fairly long lives of the wooden sleepers and for high values of r. Thus for a 14-year life for a wooden sleeper (a life easily obtained especially with creosoted sleepers) and a rate of 8 % (fig. 4) the value of β is equal to 1.52. In other words, in the case mentioned, it would not do to use sleepers of another type when the expenditure resulting from their use was more than one and a half times that of the renewal of the wooden sleepers, and this even if the life of the new design could be taken with certainty as being infinite.

4. — To pass from theoretical considerations to the practical side, the maximum life of reinforced concrete sleepers must be calculated or at least estimated. The sleeper being always taken as being perfect constructionally we cannot, none the less, forget that it is made of concrete and that in consequence its bearing surface in contact with the ballast will be subject to wear as will be the fastenings no matter how perfected the system adopted may be. As regards the bearing surface on the ballast, it must be taken into account that when tamping more concrete is wasted and to more or less extensive extent according to the conditions under which the tamping is done, but which in any case is not negligible.

Furthermore the life of the rails, sole plates, and in general the metal part of the superstructure is not eternal and moreover the needs of the traffic may evoluate in the far off future and necessitate for example a change of rails and fastenings. We do not think therefore, too great prudence is shown in estimating, naturally as an average value, the maximum practical life of concrete sleepers as being 30 years or at least the life that can be taken into serious consideration when making prudent economic comparisons.

This period of thirty years also corresponds to the value generally given by the different makers and as we have said several times, it should apply to the type of reinforced concrete that can be considered as being technically perfect. As regards the maximum value of n_2, it is always necessary not to forget that when sufficiently high values of the life are reached, an increase therein has but little influence on the value of the sleeper-year cost nor consequently on the value of the ratio β. To see this more clearly all that is needed is to calculate, using equation (2),

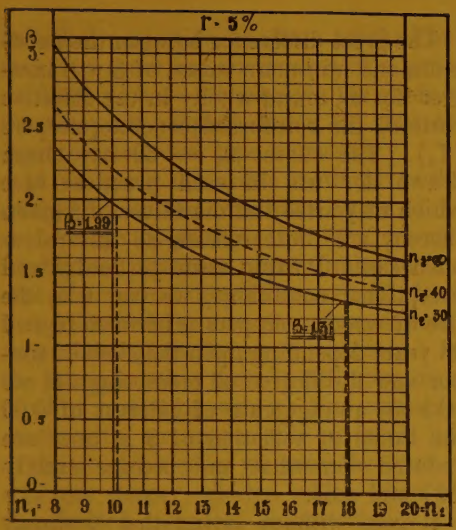


Fig. 1.

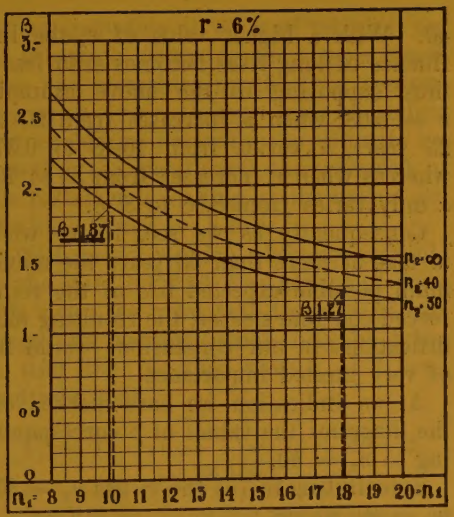


Fig. 2.

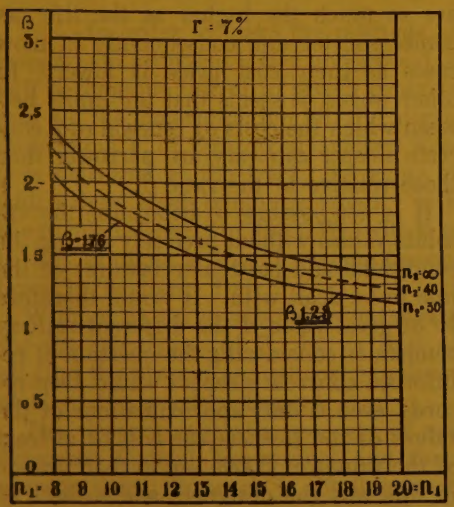


Fig. 3.

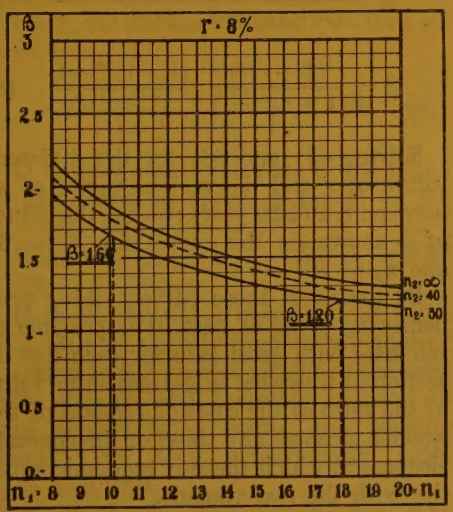


Fig. 4.

the values of α for a type of sleeper with which C may be taken as equal to 100, taking for example $r = 0.06$. It will then be noticed that the values of α in terms of n vary very quickly during the early years, to tend then with the value of $n = \infty$, towards $\alpha = 6$; thus whereas α varies from 8.72 to 7.82 whilst n increases from 20 to 25 years, α only varies from 6.90 to 6.65 when n increases from 35 to

40. With a higher value of r, the influence of long lives becomes even less : thus supposing in the above example $r = 0.08$, when n increases from 20 to 25 years, α varies from 10.18 to 9.37, whereas when n increases from 35 to 40, α only varies from 8.58 to 8.38.

Consequently as we see, if we wish to take at more than 30 years the maximum possible expected life of the reinforced concrete sleeper, the resulting modifications in our conclusions would be of very limited importance.

As an indication we have marked on the diagrams the values of β corresponding to $n_2 = 40$.

Substituting in (5) the values $n_2 = 30$, $n_2 = 40$, we get :

$$\beta = \frac{(1+r)^{n_1}}{(1+r)^{n_1}-1} \cdot \frac{(1+r)^{30}-1}{(1+r)^{30}} \qquad (7)$$

$$\beta = \frac{(1+r)^{n_1}}{(1+r)^{n_1}-1} \cdot \frac{(1+r)^{40}-1}{(1+r)^{40}} \qquad (8)$$

Solving (7) and (8) for the different values of r and the various values of n_1 between 8 and 20 years, we get the values of β shown on the curves for $n_2 = 30$ and $n_2 = 40$.

By means of these curves, taking prudently $n_2 = 30$ as base, it is possible to calculate with great ease for each line or section of line what is the maximum value of the ratio of the costs of renewal of the wooden sleepers and those of the concrete sleepers at which there is economic equality with the two systems.

As can be seen, the above mentioned value of β oscillates between very wide limits : it varies exactly from a maximum of 2.37 for a rate of interest of 5 % and a life of 8 years, for a wooden sleeper, to a minimum of 1.14 for a rate of interest of 8 % and a life of 20 years for a wooden sleeper.

The great difference between the maximum and minimum values of β will however not be found wholly in the effective costs of the reinforced concrete sleepers (T_2). The curves $n_2 = 30$ have been drawn for use in each practical case which may arise and the values of β given thereby are those relating to this calculated case. Putting aside particular and exceptional conditions, we can take the life of wooden sleepers as between 10 and 18 years depending upon the class of timber and the degree of creosoting : if we take an average rate of interest of 0.06 the limits of variation of β at once are reduced somewhat and become exactly 1.27 and 1.87.

It goes without saying that β simply indicates the ratio between the costs of renewal of the sleepers and that its values are so much the higher as the life becomes shorter and consequently in most cases as their cost price is lower. In other words, it seems that the limits between which the costs of renewal of a concrete sleeper can vary are narrower than those relative to the ratio β.

It is not possible to determine the absolute values without precisely stating the conditions and particular features of the line to be dealt with. It would therefore be of great value if the different railway companies considering the question of reinforced concrete sleepers would keep records, even if only approximations of the values of the sleeper-year cost or at least of the values of β relating to their lines : in this way the designers and makers of reinforced concrete sleepers would always be able to ascertain the extreme limits between which the cost of concrete sleepers should be kept.

All the considerations we have given attack the problem from the purely economic point of view and presuppose, not only as we have said several times, that

technical perfection has been reached but also that there are no reasons of a general kind such as for example the wish to limit imports, employ labour, etc.. favouring any particular type of sleeper.

If we apply the above methods to the calculation of the maximum value of T_2 for average operating conditions, we can readily see that the upper limits of the cost of concrete sleepers are not far from being reached for any given type selected from those of the largest dimensions. In the example below there is still some margin but as will be seen we find ourselves faced with an appreciably reduced life of the wooden sleeper whereas the type of concrete sleeper selected which gives all the desired technical characteristics has much smaller dimensions than those of other types under test.

5. — In order to make the methods of comparison proposed better understood, it will perhaps be useful to give a concrete case of the determination of the maximum value T_2 of reinforced concrete sleepers delivered at the track, the value at which these reach economic equality with the wooden sleepers in use. We will take in this example a line of average importance in northern Italy.

Without it being absolutely necessary for the calculation of C_2, let us first of all find the present annual cost of renewal α, of the wooden sleepers.

The sleepers generally used are of oak from the Central Appennines and their average price on truck is 20 lires each [dimensions 2.50 m. × 22 cm. × 13 cm. (8 ft. 2 7/16 in.×8 11/16 in.×5 1/8 in.)]. Adding the cost of carriage and of handling the sleepers, the cost in stores is about 30 lires each and on the average when laid 32 lires. We therefore have T_1 = 32 lires.

To renew a wooden sleeper costs about 8 lire, including all costs of taking it out of the track, replacing the sleeper, levelling and straightening the line, recovering with gravel ballast and relevelling but excluding naturally the ultimate renewal of the metal parts, the screening of the ballast, nor loading up the ballast etc. We have then $l_1 = 8$ lires.

Withdrawn wooden sleepers are sold to the staff for 2.50 lires each; but from this price we must take the cost of carriage and loading which may be taken as 0.50 lire : we then have $t_1 = 2$ lires, and as a total

$$C_1 = T_1 + l_1 - t_1 = 32 + 8 - 2 = 38 \text{ lires.}$$

The life of untreated oak sleepers on the line in question is rather short : it does not exceed about 10 years.

Using an average value of $r = 0.06$ we have from (2) :

$$\alpha_1 = 38 \frac{0.06\,(1+0.06)^{10}}{(1+0.06)^{10}-1} = 5.16 \text{ lires.}$$

If now we would calculate C_2 by means of the curves of figure 2 for $n_1 = 10$, $n_2 = 30$, we find $\beta = 1.87$.

From this we get $C_2 = 1.87$, $C_1 = 1.87 \times 38 = 71.06$ lires.

It should be noted here that the value of l_2 will be slightly higher than that of l_1 owing to the greater weight of the concrete sleepers and a certain increase in care needed when laying and packing them. We may consequently write $l_2 = 8.50$ lires.

To be on the safe side we may take $t_2 = 0$.

Whenever the type of sleeper used reduces the ballast needed, account of the saving should be taken here. In the case under consideration as it was considered desirable to ballast to the same cross section, this saving is negligible.

We get then finally :

$$T_2 = C_2 - l_2 + t_2 = 71.06 - 8.50 + 0 = 62.56 \text{ lires.}$$

This value is appreciably higher than that of the type adopted (about 15 %), but as we would recall to mind it represents the equivalent economic value, whereas to justify the replacement some economy however small must be expected. Consequently it can be stated that for the line in question the maximum cost of reinforced concrete sleepers delivered on the line at the point of relaying should be between 55 and 60 lires.

6. — The conclusions to be drawn from the simple considerations developed above, may be set down as follows :

1. The characteristics of a line as regards sleepers may be clearly and simply indicated by means of an ideal annual cost per sleeper which can be easily calculated and takes into account all the factors : life, cost of labour, etc... relating to the sleeper and the line (α).

2. For a supposedly technically perfect concrete sleeper, it is easy to calculate for each value of α and consequently for each line or section of line the maximum value β of the ratio between the costs of renewal of the wooden and that of the concrete sleepers, the value at which economic equivalence is reached.

In particular a purely theoretical value of β is obtained, corresponding to an infinite life of the concrete sleeper and a maximum practical value of β which it is considered prudent to calculate on a 30-year life for the concrete sleeper. Knowing the value of β it is then easy to arrive at the effective cost T_2 on the site.

3. It would be of value if the values of α and of β were given by the different companies and the different experimenters, after having carried out tests of concrete sleepers, in order to make it possible to determine if, under different conditions, the tests would be useful or at least interesting.

4. Although it is not possible to speak of limits in an absolute sense, it none the less seems that for average operating conditions the value of β should lie approximately between 1.30 and 1.90. It also appears that the present dimensions of reinforced concrete sleepers are very close to the practical limits imposed if they are to be handled, so that future improvements should concern essentially the perfection of the design and the methods of construction.

[621. 134. 3 (.43)]

The 4-6-2 high-pressure (1706 lb. per sq. inch) locomotive of the Deutsche Reichsbahn

(German State Railways),

by Fr. WITTE, Reichsbahnrat, Berlin,
and
R. P. WAGNER,
Oberregierungsbaurat a. D., Reichsbahnoberrat, Reichsbahn Central Office.

Figs. 1 to 36, pp. 824 to 843.

(From the *Zeitschrift des Vereines Deutscher Ingenieure*, *Vol.* 74, (1930) *Nos.* 31 *and* 33.)

Reference is made to the difficulties encountered in transferring the Loeffler principle from a stationary plant to a locomotive, and to the constructional methods that resulted. In building the locomotive, the performance of the heavy standard express locomotive of the State Railways was taken as a basis. The dimensions thus arrived at and the adoption of a closed high-pressure circuit are discussed as is the trend of further development.

General.

The adoption of a high-pressure system of steam generation on a locomotive leads to greater difficulties than in the case of stationary plant. One reason for this is the necessity for obtaining high performances from boilers of low weight and small dimensions; another is that the height of the boiler, upon which the natural circulation of the water depends, is strictly limited by the loading gauge of the rolling stock.

It follows that a system like the *Loeffler*, in which natural circulation is replaced by forced circulation, is bound to appeal to locomotive designers, provided that the circulating pump has no adverse effect on the economy or reliability of the engine. Confirmation on this point was afforded in the installations at Vienna (Florisdorf) and at Witkowitz by the late Professor *Loeffler*, whose early death is so much deplored.

It is true that the first of the Reichsbahn proposed designs for a *Loeffler* locomotive were not sufficiently attractive to warrant the building of a unit. A fire-grate enclosed in a refractory chamber, with a steam heater behind, and the necessary auxiliaries such as water and air pumps and circulating pumps, were arranged one behind the other on an underframe in the manner customary on electric locomotives. Such an arrangement meant great weight, large starting and radiation losses, and poor regulation of the combustion. As the Reichsbahn required the various elements of the boiler to be assembled in a similar manner to the conventional locomotive, to form the main supporting member of the vehicle, and that the steam heater should be arranged in firebox form, *i. e.* heated by direct radiation, *Loeffler* investigated the possibility of heating by direct

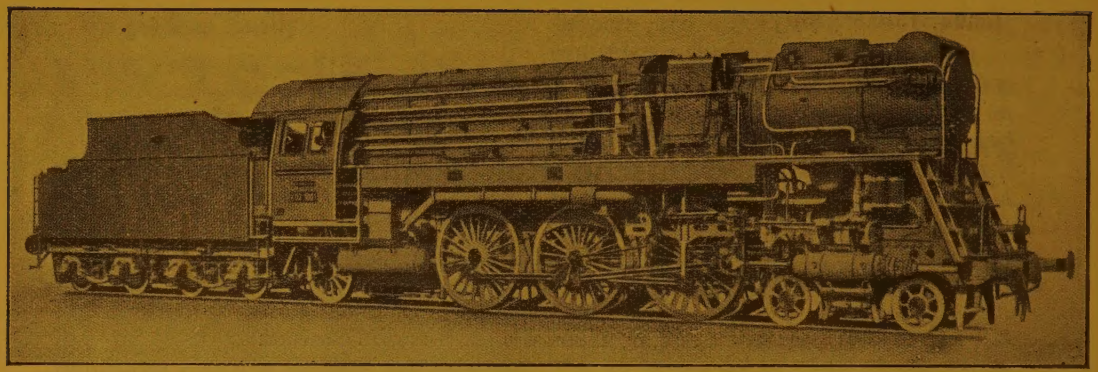


Fig. 1*a*. — 4-6-2 high-pressure [120 at. (1706 lb. per sq. inch)] locomotive of the Deutsche Reichsbahn (German State Railways.)

radiation, in the Witkowitz installation, and came to the conclusion that it would be permissible.

This opened up the possibility of building the boiler contemplated by the designers of the Reichsbahn. Close co-operation between the railway and the licensee for Germany, the Berliner Maschinenbau Aktien Gesellschaft, formerly Messrs. Schwartzkopf of Wildau, resulted in the completion of the locomotive shown in figures 1 to 7. The necessity of abandoning all the familiar and well-known elements of locomotive construction rendered the working out of the design both difficult and interesting, and there resulted finally an engine that marks a definite stage in the development of the century-old locomotive of Stephenson.

For various reasons it was impossible to transfer to the locomotive the system that had been tried out on stationary plant. Such installations almost invariably work with a closed circuit, *i. e.* condensing and with pure feed water for the boilers. The use of condensing, which would entail the employment of a turbine (1), would have discounted the value of the system for locomotives from the outset. The use of a high pressure-drop on locomotives, for outputs that are small compared with stationary plants, limits the practibility of a high-pressure turbine, quite apart from the inherent disadvantages of the turbine from the operating point of view. The reciprocating engine is still unequalled for railway operating conditions, and the fact that the *Loeffler* locomotive incorporates this type of heat engine is at once a point in favour of the system.

If the possibility is dismissed, as not having yet been tried out, of working the Loeffler system entirely without using the circulating principle, the use of the high-pressure feed water circuit must be adopted in order that the latent heat of the steam expanded in the high-pressure engine may be abstracted for the production of further steam in an open low-pressure evaporator.

The Loeffler process allows the evapo-

(1) *Glasers Annalen*, Jubilee number, 1927, p. 29.

rating drum to be placed in any position, independent of the source of heat. This means that the heat-absorbing surface, necessarily constructed in the form of nests of tubes since no other design is permissible for the high pressure in question, could be designed in compliance with the practical requirement that the superstructure should be kept as light as possible. This would not have been the case if a collector drum had been mounted above the tubes which would have increased the difficulties of construction very considerably. On the other hand the tubular form of heating surface renders it difficult to produce a design that is in line with the conventional locomotive boiler which serves as a supporting and stiffening member of the structure.

A decisive factor in judging the Loeffler system is its inherent safety. The difficulty of ensuring proper circulation of the water increases with the pressure if it depends solely upon natural circulation caused by differences of heat and specific gravity. The forced circulation which results from pumping the heat-carrying steam gives a sure guarantee against local overheating and its consequences; at the same time it enables the production of steam to be regulated very completely in conjunction, of course, with the firing, and to an extent that cannot be easily achieved with other systems although it is so essential in locomotive operation.

Construction programme.

In recent years the Reichbahn have coordinated their experimental work on large engines with the building programme for their largest express engines of the 4-6-2 standard type, series 01 and 02. By doing this, there has been a common basis for all research work, which allows a direct comparison of fuel economy, maintenance costs, operating qualities, etc... Moreover both of the selected designs embody the most up-to-date ideas in the field of locomotive construction, and, as they are capable of giving the best possible performance figures, they afforded an ideal means for establishing exactly what saving was attribuable to the use of high-pressure steam.

The locomotive in question has an axle loading of 20 t. (19.68 Engl. tons) on the coupled axles, a wheel diameter, as express engines, of 2 000 mm. (6 ft. 6 3/4 in.), and a boiler rating of 2 500 to 2 600 H. P.). The stipulated guarantee of 42 % saving in fuel over that of the standard locomotive permitted a reduction of approximately the same amount in the grate area, so that in spite of the output remaining the same the work of firing was considerably reduced.

It was necessary to modify the cylinder arrangement. The use of a closed high-pressure water circuit with a low-pressure evaporator coupled to it, rendered a three-cylinder design feasible; and as these are connected indirectly, through the heat content of the high-pressure steam used in the high-pressure cylinders, what is practically a compound engine results. The utmost advantage being taken of the high-pressure system, it was possible to transfer about 2/3 of the work to the two outside high-pressure cylinders, whilst a single low-pressure inside cylinder took over the remainder of the load.

The normal steam conditions in the boiler are about 110 at. (1 564 lb. per sq. inch) and 460° C. (870° F.). The pressure and temperature reached in the

high-pressure cylinders is about 105 at. (1 493 lb. per sq. in.) and 450° C. (842° F.). From these conditions expansion takes place to 17 atm. (242 lb. per sq. inch) and 250° C. (482° F.). The steam having given up the greater part of its capacity for doing work is then taken to a heat exchanger where it gives up its latent heat in producing steam at low-pressure. It leaves the heat exchanger at the same pressure and at about 203° C. (400° F.).

Of 689 k. cal./kgr. (1 240 B. T. U./lb.) which it had at the inlet to the low-pressure boiler, 689-207 = 482 k. cal. (867 B. T. U./lb.) are used for evaporation. The condensate from the high-pressure side of the heat exchanger is led back to the high-pressure circuit. The feed to the low-pressure boiler enters at 14.5 at. (206 lb. per sq. inch) and 15° C. (59° F.) and after evaporation is at 195° C. (483° F.) or contains 665 k. cal. (1 197 B. T. U./lb.). Therefore it requires 650 k. cal./kgr. (1 170 B. T. U./lb.). Since only 482 k. cal. (867 B. T. U./lb.) is available, the amount of low-pressure steam produced is about 74 % of the high-pressure steam that is condensed. Of this amount the auxiliaries take

	without steam heating	with steam heating
at full load . .	20 %	28 %
70 % load . . .	15 %	27 %

The balance of the low-pressure steam does work in the locomotive engine proper. The quantity of fresh water used by the locomotive corresponds to this portion, i. e. is about one half of that required by a locomotive of the ordinary type . The exhaust from the low-pressure cylinder provides the automatic adjustment of combustion to load that is such an important advantage of the ordinary locomotive, and gives an ideal means to that end.

The mean operating pressure of 110 at. (1 564 lb. per sq. inch), mentioned above, can be raised to about 120 at. (1 706 lb.) when the locomotive is stationary. By suitably connecting the low-pressure boiler to the high-pressure boiler, this high pressure can be made use of and nearly all steam losses avoided whilst the engine is standing.

The high-pressure boiler.

The various parts and their connections are shown in the diagram, figure 8. The mean temperature of the steam being higher, corresponding to the greater pressure, the temperature of the flue gases at the end of the high-pressure boiler is actually higher than in an ordinary boiler, even with an appropriate arrangement of the preheaters. The various heating surfaces, particularly the air heater, are accordingly arranged to ensure a very complete utilisation of the flue gases and a correspondingly high boiler efficiency.

The position of the evaporator drum being quite independent of the heating surfaces rendered it possible to assemble the various units away from a large number of similar parts which in their present form provide a basis for the development of a high-pressure locomotive boiler of the purely tubular type.

The drum could be placed lengthwise between the frames, thus allowing a completely free space for the arrangement of the boiler. A drum construction of a particularly appropriate type for high-pressure locomotives was thus originated. By avoiding openings of any kind in the body and bringing all the connections into one end, it was possible to construct a drum of 840 mm. (33 9/16 inches) internal diameter with a wall thickness of

4-6-2 high-pressure [120 at. 1706 lb. per sq. inch] locomotive of the Deutsche Reichsbahn. Built by Messrs. « Berliner Maschinenbau A.-G. (formerly L. Schwartzkopff) » Berlin.

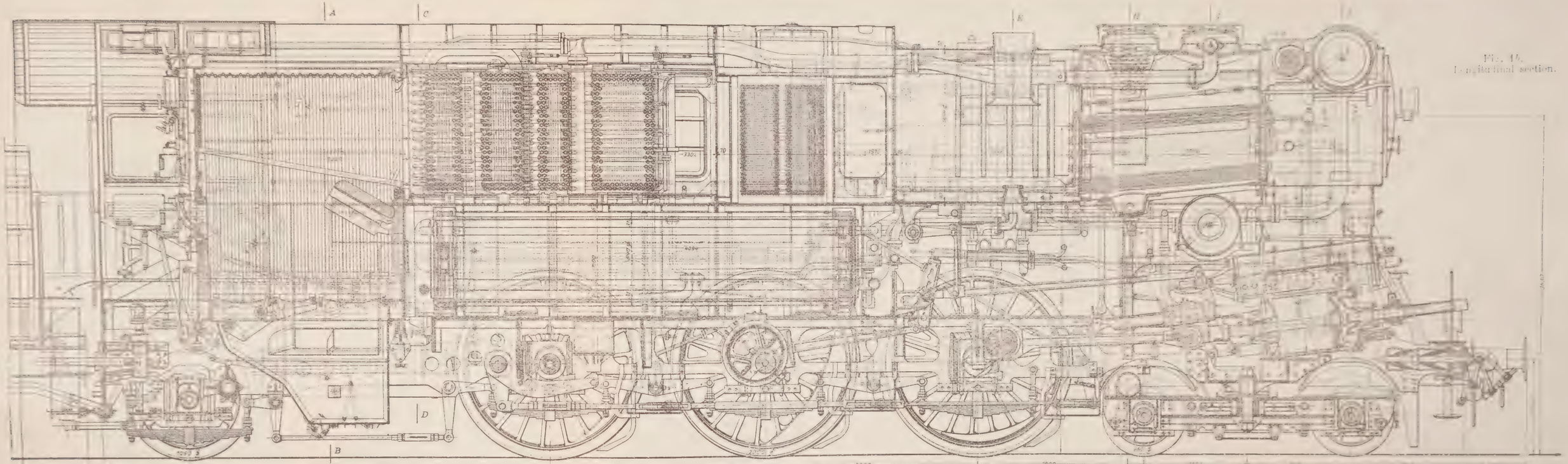


Fig. 44.
Longitudinal section.

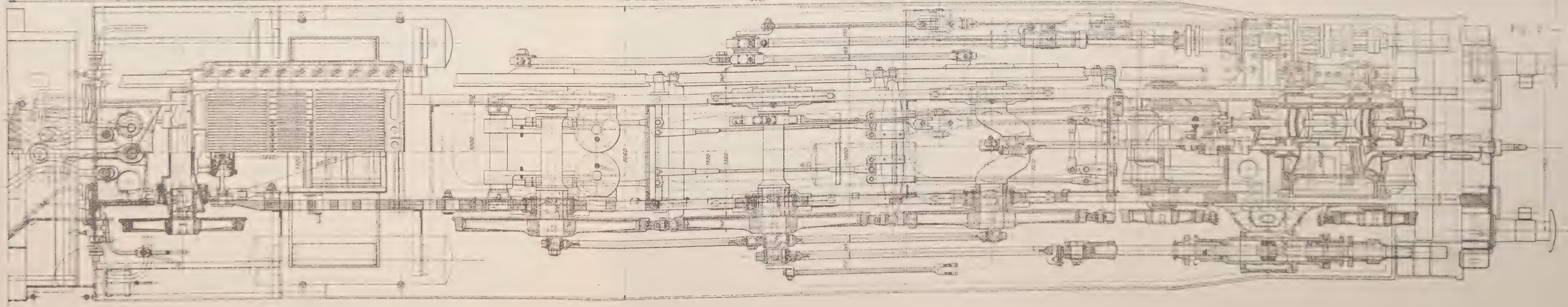


Fig. 45. — Plan.

4-6-2 high-pressure [120 at. (1706 lb. per sq. inch)] locomotive of the Deutsche Reichsbahn.

Cab.

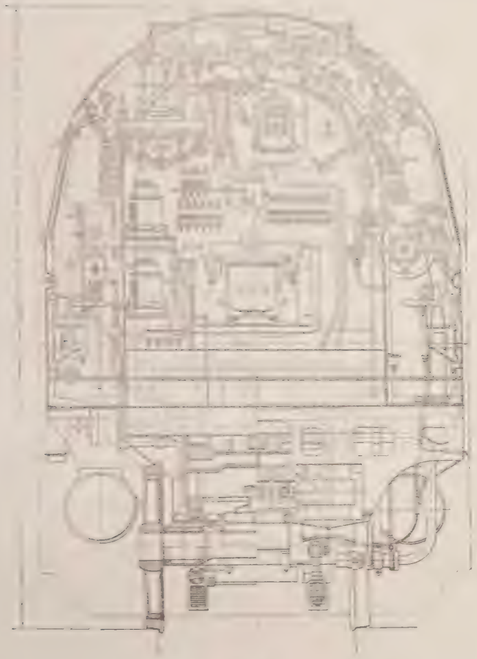


Fig. 3.

Section *A—B*
Rear wall of firebox looking towards cab.

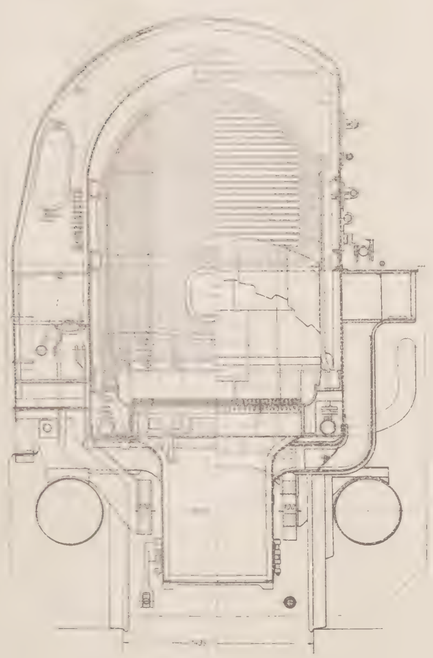


Fig. 4.

Section *A—B*
Looking on front wall of firebox.

Section *E—F*
Looking towards the cylinders.

Section *E—F*
Looking towards the cab.

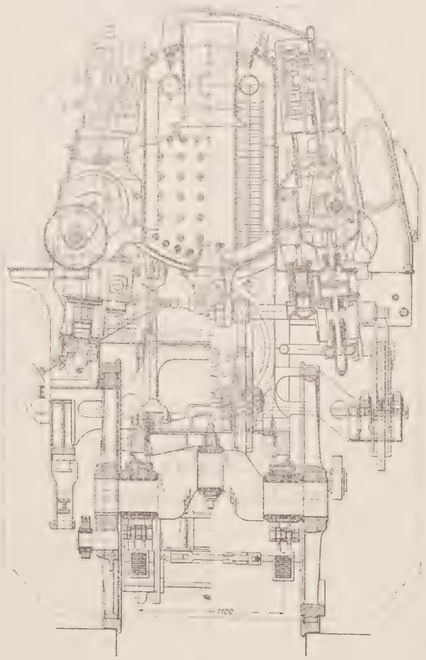


Fig. 5.

Section *G—H*
Looking towards the cab.

Section *J—K*

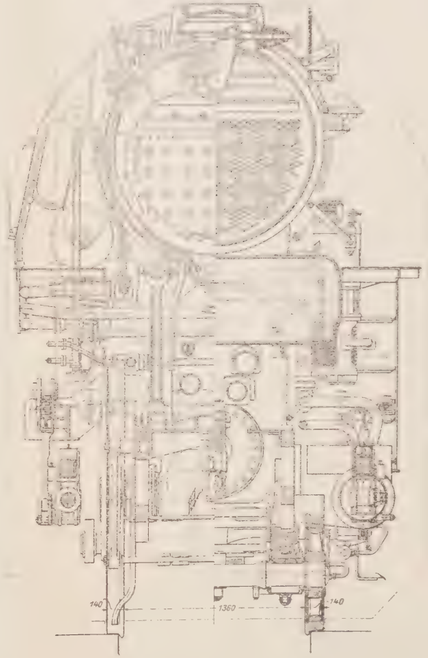


Fig. 6.

Section *L—M*

Section *N—P*

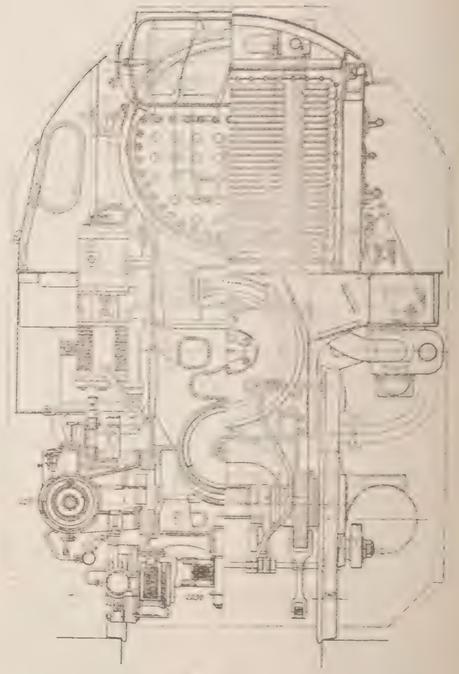


Fig. 7.

Diameter of high-pressure cylinder	220 mm. $\left(8\frac{11}{16}\text{ inches}\right)$.	Steam pressure, L. P. boiler	14-15 at. (199-213 lb. per sq. in.).
— low- —	600 mm. $\left(23\frac{5}{8}\text{ inches}\right)$.	Grate area	2.4 m² (25.83 sq. feet).
Stroke	660 mm. (26 inches).	Heating surface of H. P. superheater (heated by combustion gases)	90 m² (968 sq. feet).
Steam pressure, H. P. boiler	120 at. (1706 lb. per sq. in.)	— H. P. preheater — —	71 m² (764 sq. feet).
		— L. P. superheater — —	32 m² (344.5 sq. feet).

Heating surface of air preheater (heated by combustion gases)	85 m² (915 sq. feet).
Nett weight	109 700 kgr. (108 Engl. tons) approx.
Weight in service	114 000 kgr. (111.2 —) —
Adhesive weight	60 000 kgr. (59 —) —
Maximum permissible speed	120 km. (74.5 miles) per hour.

31 mm. (1 7/32 inches), in spite of the high pressure. The use of flat end-discs gives the advantage that they can be screwed in and further secured by rings shrunk on outside. A noteworthy feature of this method of construction is the ease of forging and suitability for economical machining in the shops.

The materials used are shown in table I.

TABLE I.

Materials used in construction of high-pressure evaporating drum.

Part.	Material.	Tensile strength at 20° C. (68° F.)	Tensile strength at 365° C. (689° F.)	Elastic limit at 20° C. (68° F.)	Elastic limit at 365° C. (689° F.)	Elongation
Drum . .	Chrome-nickel steel	70-80 kgr. (44.4-50.8 tons)	47.5 kgr. (30.2 tons)	50 kgr. (31.7 tons)	29.5 kgr. (18.7 tons)	15
Covers and rings. .	Chrome-nickel steel	75-85 kgr. (47.6-54 tons)	52.5 kgr. (33.3 tons)	55-60 kgr. (34.9-38.1 tons)	34 kgr. (21.6 tons)	15

The drum is fixed rigidly to the frame at its front end and is free to expand at the back. It is held in position at both ends by wide steel straps.

The considerable variation in the amount of water in the drum, due to slowing up and acceleration, and the comparatively small steam space, render it necessary to give special consideration to the arrangement of the steam outlet pipe. Running the entire length of the steam space is a pipe provided with holes which form separate steam passages, and on the outiside of the drum these are connected together. Saturated steam is drawn off by the circulating pump, and even if one end of the pipe is submerged under water, there are always sufficient outlets uncovered at the other end, and the resistance to flow being less, steam is drawn off through them.

Firebox.

The saturated steam is led into the nest of tubes surrounding the firebox, and the greatest heat drop occurs at this point between the grate radiation and the entering steam; effective cooling of the tubes exposed to the direct radiant heat therefore results. It was necessary to arrange the system of tubes as a parall grouping of a large number of elements; there are twelve such elements at the two sides and four at the rear wall. The amount of heating surface provided in each element is determined by the steam flow and the maximum permissible temperature that is aimed at.

As earlier experience (1) had shown that the radiation heating was irregular along the firebox, experiments were first directed to obtaining uniform heat absorption by suitable distribution of the steam amongst the various similar tube units. The results obtained led to the insertion of throttle diaphragms between the flanges of the elements and the headers at the base of the side walls. All the superheater tubes are of 60.11 steel with

(1) *Zeitschrift des Vereines deutscher Ingenieure* (VDI), vol. 72, 1928, p. 1521.

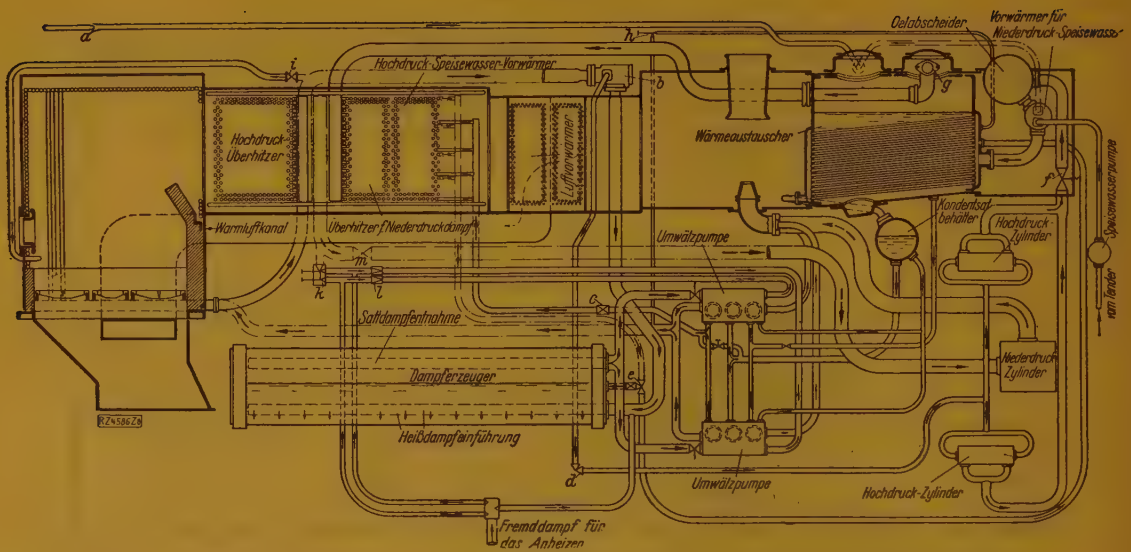


Fig. 8. — Diagram of the steam generating system of the Loeffler locomotive, showing the high-pressure closed circuit and the low-pressure part.

a = Jet pump. — *b*, *c* = Retaining valves. — *d* = High-pressure regulator. — *e* = Two-way valve. — *f* = Safety valve. — *g* = Stop valve. — *h* = Overflow valve. — *i* = Blow-off valve. — *k* = Stop valve of pumps. — *l* = Admission valve. — *m* = Low-pressure regulator.

Explanation of German terms in diagram:

Dampferzeuger = Steam generator. — Fremddampf für das Anheizen = Steam from external source for starting up. — Heissdampfeinführung = Inlet for superheated steam. — Hochdruck-Speisewasser-Vorwärmer = High-pressure feed water preheater. — Hochdruck-Überhitzer = High-pressure superheater. — Hochdruck-Zylinder = H. P. cylinder. — Kondensat behälter = Condensate tank. — Luftvorwärmer = Air preheater. — Niederdruck Zylinder = L. P. cylinder. — Oelabscheider = Oil separator. — Sattdampfentnahme = Outlet for saturated steam. — Speisewasserpumpe = Feed water pump. — Überhitzer-Niederdruckdampf = Superheater for low pressure steam. — Umwalzpumpe = Circulating pump. — Vom tender = From tender. — Vorwärmer für Niederdruck-Speisewasser = Preheater for low-pressure feed water. — Wärmeaustauscher = Heat exchanger (Low pressure boiler heated by condensation high-pressure exhaust). — Warmluftkanal = Hot air duct.

diameters of 30/38 mm. (1 3/16 in. — 1 1/2 in.). The arrangement of the elements is shown in figure 9.

Auxiliary superheater.

The firebox superheater is heated irregularly due to the individual elements being affected by variations in firing. To compensate for this, the steam is led from the left-hand heater to an auxiliary superheater which operates on a subdivided counter-current principle. The steam flows from a vertical distribution pipe through 26 coils, each of eight legs, placed across the path of the flue gases, and is collected again in a second vertical header.

The tubes of the auxiliary superheater carry the hottest steam. In order that the final average superheat may be as high as possible the nests of tubes are connected in such a way that as the cold steam passes from the firebox to the hottest part of the superheater, it first takes up the directly radiated heat, through a protective grating.

The same fundamental principle of

construction has been used for the whole of the heating surfaces in the main boiler structure. Straight lengths of tube are welded to cast steel return bends, figure 10, to form layers which are arranged in series or parallel to give the required heating surface and velocity. Welding has been employed extensively in this method of construction, and joints, which can only be regarded as a possible source

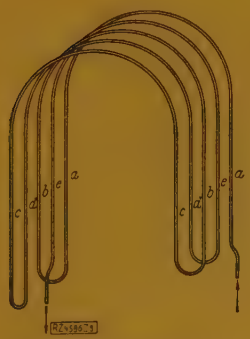


Fig. 9. — Arrangement of tubes to firebox superheater elements.

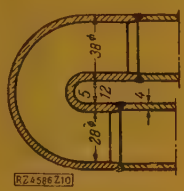


Fig. 10. — Return bend of an element of the high-pressure auxiliary superheater.

of trouble, have been eliminated as far as possible. The process of manufacture (1) and the corresponding adaptations of equipment employed in this case differ entirely from the usual methods, and are bound to lead to cheapening of the costly method of boiler construction. With the change over to water — and steam — tube boilers, the welding process will gain ground more and more over the expensive workmanship of the locomotive boiler smithy.

This clearly entails a revolution in construction methods. In the welding to the headers of the vertical rows of connections it is necessary for the tubes to be taken through to the inside. The provision of the sectional areas necessary for the flue gases and for their proper velocities, and more particularly the accommodation of the heating surfaces is facilitated by the use of cast steel bends throughout.

(1) See *VDI Nachrichten*, 14 May 1930, No. 20.

High-pressure preheater.

In front of the high-pressure superheater, in the direction of the temperature gradient of the flue gases, are connected the low-pressure superheater, high-pressure heater, and air heater, all built up on the same lines. The high-pressure preheater takes a somewhat different form. One portion of the tubes is formed into a flat wall, by welding wing pieces between the tubes, for the purpose of providing an insulating lining for the boiler casing. In addition to this function, the high-pressure preheater plays a special role in the general scheme of the locomotive owing to its importance in assisting the high-pressure superheater. According to the position of the various sections of the preheater — on the enclosing casing or in the tube nest — and the surrounding temperature, they are arranged in groups suitably connected together.

The cold water flows from the pump first to the section that is mounted inside the enclosing casing, and then through four nests of tubes in the opposite direction to the flow of the flue gases. These four main coils are connected in parallel in order to secure such velocities in the 30/38-mm. (13 3/16 in. — 1 1/2 in.) tubes as are appropriate for the transference of the heat. The arrangement of the side walls in the actuel boiler structure is shown in figure 11. After loosening the fixings and connecting flanges, the individual sections can be withdrawn

upwards, commencing with the cover section, and finally the tube nests are free and can also be lifted out.

The whole of the heating surfaces are carried on a box girder which is supported on the side frames, with freedom to expand longitudinally. The framework forming the side walls is built partly of cast steel sections, i. e. the firebox foundation ring and the upper flange, which afford convenient supports for the tubes. The firebox is mounted in the usual way with slides and brackets.

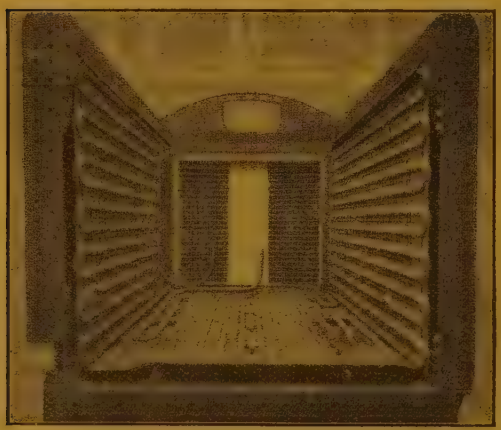
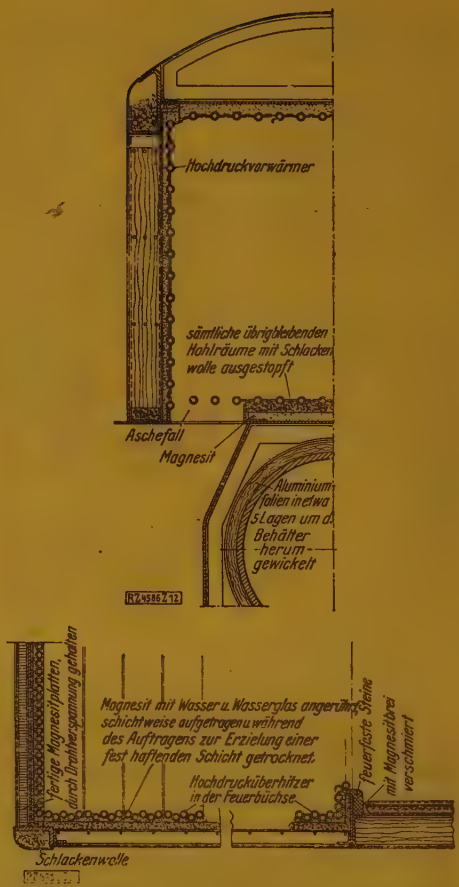


Fig. 11. — Portion of the main boiler casing (superheater chamber).


Hochdruckvorwärmer
sämtliche übrigbleibenden Hohlräume mit Schlackenwolle ausgestopft
Aschefall
Magnesit
Aluminiumfolien in etwa 5 Lagen um d. Behälter herumgewickelt
Fertige Magnesitplatten, durch Drahtverspannung gehalten
Magnesit mit Wasser u. Wasserglas angerührt schichtweise aufgetragen u. während des Auftragens zur Erzielung einer fest haftenden Schicht getrocknet.
Hochdrucküberhitzer in der Feuerbüchse
Feuerfeste Steine mit Magnesitbrei verschmiert
Schlackenwolle

Figs. 12 and 13. — Heat insulation and packing of the firebox and boiler casing.

On both sides of the boiler casing there are ash pockets which can be cleaned from outside underneath the frames. A soot blower is fitted for keeping the tubes clean; it consists of vertical nozzle pipes between the nests of tubes, which can be rotated so that the steam jets can play on every part of the tubes. The method of insulating and packing the space between the tubes and the boiler casing is illustrated in figures 12 and 13.

Explanation of German terms:

Aluminiumfolien in etwa 5 Lagen um d. Behälter herumgewickelt = Five layers of aluminium foil wrapped round drum. — Aschefall = Ash pockets. — Fertige Magnesitplatten, durch Drahtverspannung gehalten = Prepared magnesite sheets held in place by wire netting. — Feuerfeste Steine, mit Magnesitbrei verschmiert = Fireproof bricks coated with magnesite cement. — Hochdrucküberhitzer = High-pressure superheater. — Hochdruckvorwärmer = High-pressure preheater — Magnesit = Magnesite. - Magnesit mit Wasser, etc. = Magnesit laid on in layers mixed with water and water glass and dried as put on, to secure a thoroughly adhesive coating. — Sämtliche übrigbleibenden Hohlräume mit Schlackenwolle ausgestopft = All other spaces filled with slag wool. — Schlackenwolle = Slag wool.

The air preheater.

For abstracting the final portion of heat from the flue gases, a preheater is installed at the front end. The gases divide into two parallel streams at this point and give up their heat to the tubes through which the air is forced by the head draught and the suction action of the blast pipe. To reduce the resistance as much possible, the nests of tubes are inclined slightly towards the direction of motion. There are two nests of 20/22 mm. (25/32) in. — 7/8 in.) St. 34 tubes on each side of the locomotive, and all four discharge into an equalising box on the centre line of the engine.

The larger volume of the air with increasing temperature is taken care of by increasing the number of tubes in the second nest from 564 to 658. With 2 444 tubes, each 500 mm. (19 11/10 inches) long, preliminary tests have shown that the air is heated to 140° C. (284° F.). The air is led to the ash pan through two sheet-metal ducts arranged under the side frames on either side of the boiler. These ducts have double walls and are insulated with aluminium foil. Beyond the air heater the boiler is cylindrical in shape, enclosing the smoke box and forming a support for the circulating pumps.

The heat exchanger.

The heat exchanger is not in contact with the flue gases but is heated solely by the exhaust steam from the high-pressure cylinders. The bottom is inclined slightly upwards corresponding to the slanting arrangement of the tubes. Exhaustive tests have shown that an inclination of 1 in 25 is the most favourable for the draining of the condensate. A total of 586 tubes of 19.5/23.5 mm. (0.77/0.93 inch) diameter is provided. The heating surface is sufficient for an evaporation of about 4 600 kgr. (10 120 lb.) at 14 at. (199 lb.). The exchanger is equipped in the manner usual in low-pressure boilers.

Since the losses in the high-pressure circuit have to be replaced from this source, care has been taken to incorporate the usual provision for ensuring clean water by fitting a sludge separator (1). Steam is taken from the front dome.

Since the low-pressure steam is used for driving the pumps, in view of the necessity of providing steam from an external source for starting up, it is desirable to superheat it as much as possible in order to obtain the highest overall economy for the locomotive. The steam for the pump is therefore taken from the hot side of the low-pressure superheater. As this portion of the steam is being used continuously it serves the purpose of keeping the superheater cool, e. g., when the locomotive is stationary.

To avoid having to separate the superheater into two parts, a main superheater and a separate section for the auxiliaries, it is necessary to depart from conventional locomotive practice and to fit a superheated steam regulator. This regulator is generally similar to the standard Schmidt & Wagner type of high-pressure regulator (2).

The regulators are fitted on the right-hand side of the locomotive underneath the side frames. As both the boilers are coupled together as steam generators when the engine is running, the steam taken from the high-pressure circuit through the high-pressure regulator determines the steam production in the low-pressure boiler and also the volume

(1) *Zeitschrift des VDI*, vol. 70, 1926, p. 1740.
(2) *Zeitschrift des VDI*, vol. 70, 1926, p.1731.

of steam available for the low-pressure cylinder. Consequently the two regulators could be coupled together by the operating rod. The high-pressure regulator, figures 14 and 15, consists of a housing and cap machined from the solid steel (60.11 steel). The main and pilot valves slide in a bushing of special steel which is held in place by the cap. The main valve is made steam tight from the cap by three rings, and the space inside the cap is maintened at boiler pressure when the valve is closed by means of a throttled passage round the rod that operates the auxiliary valve.

When the pilot valve lifts, the steam escapes from the cap more quickly than it can be replaced by fresh steam passing through the passage; this action, in conjunction with the increased pressure in the outlet pipe produces a difference in pressure between the valve chamber and the cap, and the main valve lifts.

Boiler details.

The various details of construction and equipment are important in the development of a high-pressure boiler. It has already been pointed out that welding has been used in order to avoid or minimise the number of bolted joints which have to be made tight against the high pressure, consistent of course with maintenance considerations. All high-pressure connections have flanges of 60.11 steel and wherever space and the assembly conditions permit they are of the coned type with a parallel portion in front of the cone. Figure 16 shows a typical bend construction with a flange of this type; it is machined from the solid and forms a safe and easily detachable joint of small size and weight. Figure 17 shows an outlet in the cover of the evaporator drum; between the two pipes that are to be connected there is an independent sleeve of 34.11 steel expanded in place to form a smooth passage through the cover. This arrangement also protects the hole in the cover from the direct contact of the high velocity steam, and from the high temperature as in the case of the superheated-steam pipes.

The method of connecting the firebox elements to the headers is shown in figure 18. It has to be capable of being readily disconnected so that the elements can be withdrawn from above. All bolts on the connections have spring washers in order to allow for expansion.

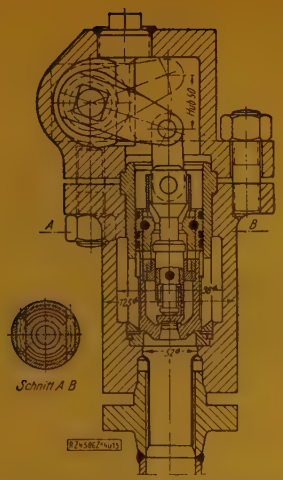
In contrast to the ordinary boiler containing a large volume of water, the tubular boiler now under discussion has a limited capacity for doing damage in the event of an explosion; this is due to the much smaller quantity of energy that is available for release.

Danger from rupture of individual tubes can be still further reduced in a simple manner by fitting non-return valves. As shown in figure 8 extensive use has been made of such valves. The principle of the design adopted is illustrated in figure 19. This valve is fitted behind the auxiliary superheater and prevents the contents of the drum from being released if a superheater tube should fail. The surfaces are preserved by the use of rustless steel. The valve body is forged from 60.11 steel.

The stop valve shown in figure 20 is of ordinary design but is made of rustless steel.

A detail of the high-pressure boiler equipment that has to be carefully designed is the water-level indicator, figures 21 and 22.

A direct indication cannot be obtained as the drum is situated at too low a level.



Figs. 14 and 15. — High-pressure regulator valve.

Fig. 16. — Bend for high-pressure pipe.

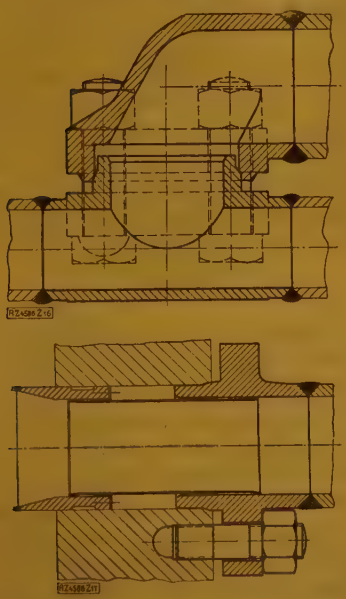
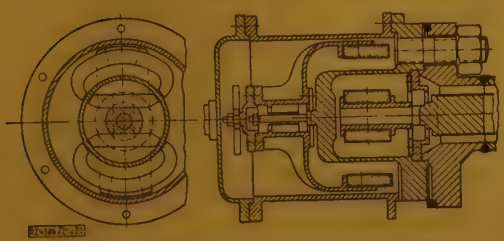


Fig. 17. — Connection piece for superheated steam inlet.



Figs. 21 and 22. — Parts of water level gauge.

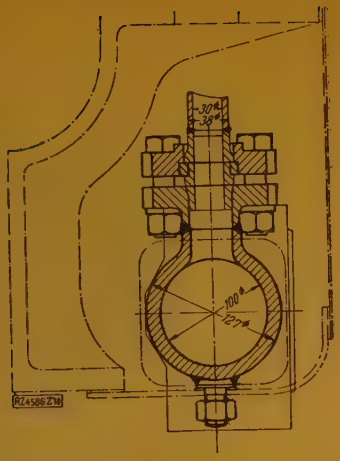


Fig. 18. — Header for firebox elements.

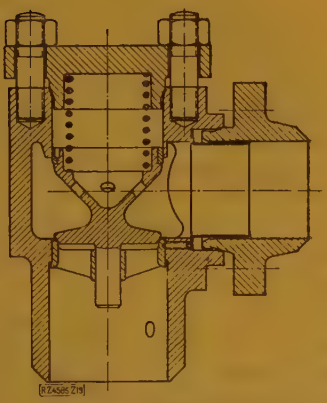


Fig. 19. — Retaining valve.

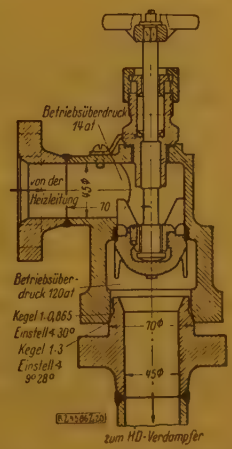


Fig. 20. — High-pressure stop valve.

Explanation of German terms :

Betriebsüberdruck = Operating pressure. — Von der Heizleitung = From superheated steam main. — Kegel = Cone. — Einstell ∢ = Angle of cone.

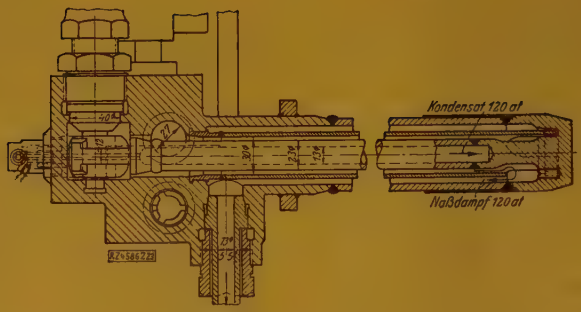


Fig. 23. — Thermostat for temperature checking.

Explanation of German terms :

Kondensat = Condensate. — Nassdampf = Saturated steam.

A float is arranged in a vessel connected to the drum and its rise and fall are transmitted by a wire to a spindle which in turn communicates with the cab. The spindle does not emerge from the closed vessel but transmits its movement by a magnetic coupling, thus avoiding the friction of a stuffing box.

This device has not the same importance in the present case as it would have in the ordinary type of boiler. A protective device for the temperature of the superheater system is much more important in the Loeffler boiler.

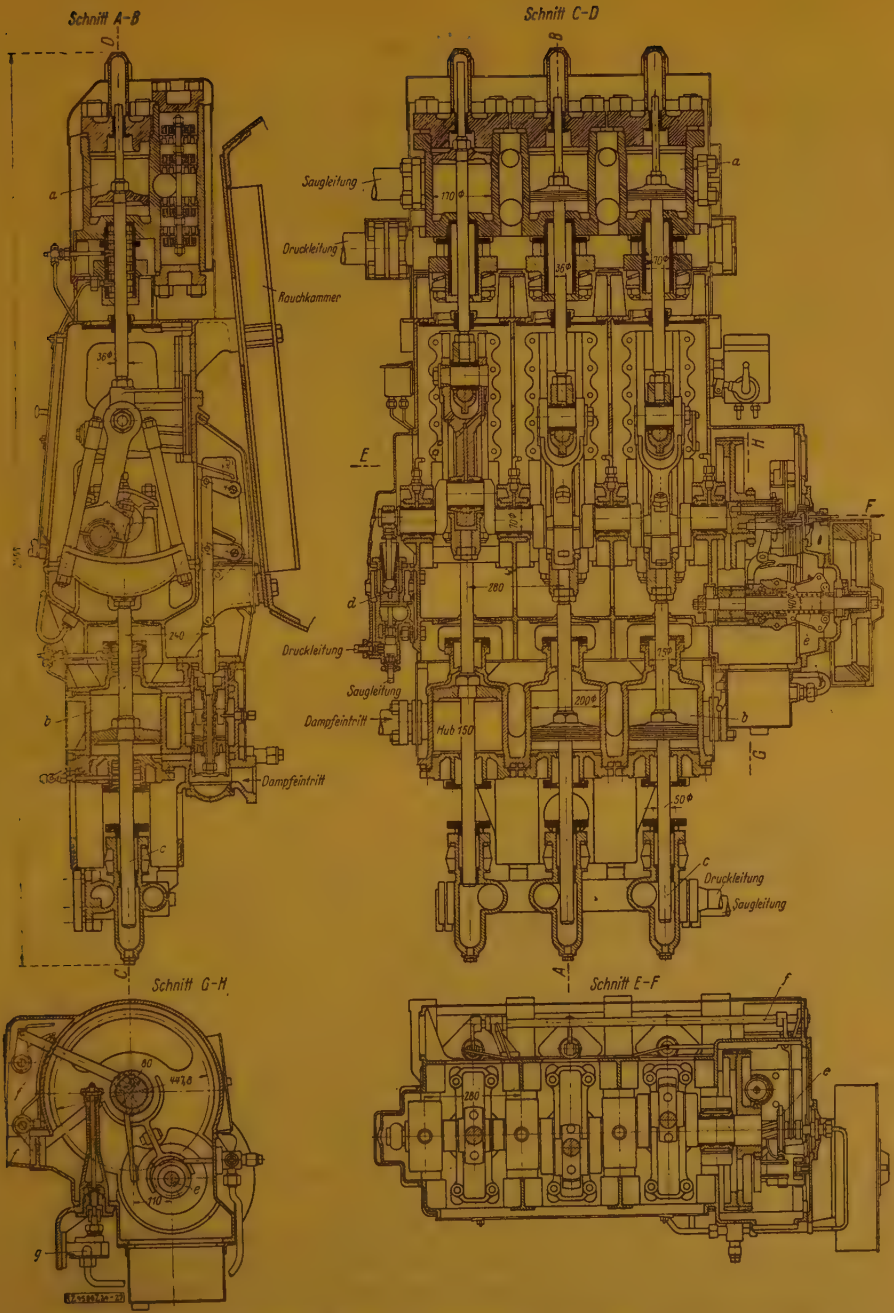
It is imperative that the maximum temperature permissible for the tube material should in no circumstances be exceeded, since the mechanical stressing of the material has already been pushed as far is it is advisable to go at high temperatures, and the steam temperature has to be very high in order to reduce the re-circulation to a minimum. In addition to pyrometers, a thermostat device that was developed on the stationary Loeffler boiler has been tried; this is shown in figure 23. A straight double tube is fitted in the furnace and saturated steam passes through the inner tube and returns along the annular space between the two. The resulting difference of temperature between the two tubes causes a relative displacement that is used to indicate the temperature of the firebox tubes.

The circulating pumps.

The most important features of the Loeffler boiler, at any rate when the boiler is considered as the starting point in the process of power production, is the circulating pump, figures 24 to 27.

Just as two independent pumps are always fitted on the usual type of boiler, here also the same precaution is taken to obviate the possibility of the locomotive being put out of action by a fault in one pump. The design of the pumps has been worked out with the idea of incorporating in a single unit, as many of the auxiliaries for the high-pressure boiler as possible (1). Each unit therefore com-

(1) See *Zeitschrift des VDI*, vol. 70 (1926), p. 1565 : Imfeld, « Die Turbinenlokomotive der Firma J. A. Maffei (The turbine locomotive of Messrs. Maffei).



Figs 24 to 27. — Circulation pump for the heat-carrying steam of high-pressure part.

a) Circulation cylinder. *b*) Driving cylinder. *c*) Feed pump. *d*) Make-up feed pump. *e*) Centrifugal governor. *f*) Piston valve actuating gear. *g*) Oil circulating pump.

Explanation of German terms:

Dampfeintritt = Steam inlet. — Druckleitung = Delivery pipe. — Sangleitung = Suction pipe. — Schnitt = Section.

prises the circulating pump cylinders at the top, feed pumps at the bottom and the working cylinders in the middle. When the engine was designed there was not enough experience available on rotary circulation pumps to work at high temperature, and although that would have been an ideal type for the purpose, it was necessary to adhere to the reciprocating type. The latter certainly has the advantage that the feed and auxiliary feed pumps could be combined with it.

The two sets of pumps are identical and interchangeable, and each is designed for 75 % of the full output of the boiler. In normal service only one pump has been run, since it is found in practice that the maximum output is very seldom called for. Smooth operation and uniform delivery are ensured by using a three-cylinder construction throughout with a three-throw crankshaft and a flywheel.

Low-pressure superheated steam is used for driving and is distributed by piston valves and worked expansively to secure economical consumption.

The valve gear is driven from a common eccentric, with a 120° displacement,

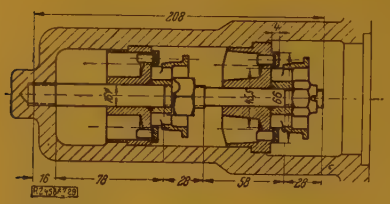


Fig. 29. — High-pressure valve of feed pump.

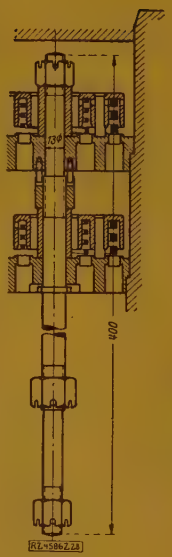


Fig. 28. Valve to cylinder of circulating pump.

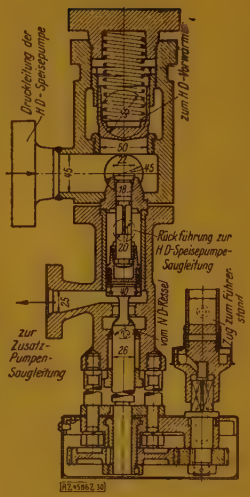
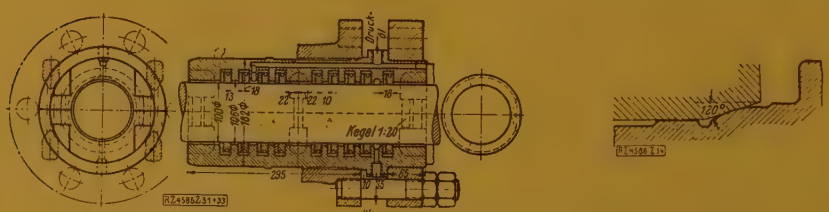


Fig. 30. Regulating valve for feed and make-up feed to high-pressure boiler.



Figs. 31 to 34. — Stuffing box for high-pressure cylinder of locomotive.

Explanation of German terms in fig. 30.

Druckleitung der H. D... = Steam pipe to high-pressure feed pump. — Rückführung zur H. D... = Return to suction pipe of high-pressure pump. — Vom N.D.-Kessel = From low-pressure boiler. — Zug zum Führerstand = To driver's cab. — Zug H. D.- Vorwärmer = To high-pressure feedwater heater. — Zur Zusatz-Pumpen-Saugleitung = To suction pipe of make-up pump.

and a double regulator alters the eccentricity so that up to 60 r. p. m. there is 90 % of full admission, while beyond this speed up to 100 r. p. m. the first regulator reduces the cut-off; at higher speeds the second regulator comes into operation and throttles the steam right down at 370 r. p. m.

The pumps have a forced oil circulation so that they require no special attention when running. The three cylinders of each circulation pump are made from a solid steel block. The four suction and delivery valves on each cylinder have to work against a pressure of only 4 at. (57 lb.), corresponding to the frictional resistance of the superheater tube system; hence they are constructed with automatic double ring valves, figure 28.

The stuffing boxes have seven cast-iron packing rings and expansion is provided for by strong springs between the flange and the securing nuts. The continuous piston rods terminate at the lower end in the cast-steel bodies of the condensate pump; the suction and delivery valves of the latter are arranged so as to be easily accessible from the outside, figure 29. These disc valves have to operate at between 17 and 120 at. (242 and 1 706 lb.), and they are accordingly made of V2A steel 4 mm. (5/32 inch) thick.

Since the various pumps are coupled together some arrangement is necessary for adjusting the delivery of condensate and make-up feed water to suit the quantity of steam circulated. The regulating device for this purpose is shown in figure 30. If the feed is reduced, it permits a part of the condensate to be bye-passed back to the suction side, or if the full amount of condensate is being delivered an additional supply of water can be transferred from the heat exchanger to the high-pressure circuit. The device is under the control of the driver.

Stop valves are inserted in the suction and delivery pipes. The safety valves, of the *Ackermann* type [1], are mounted directly on the valve casing in the suction pipe.

The performances of the component pumps of each composite set are as follows :

a) Circulation pump.

The volume of steam circulated depends on the pressure and temperature of the high-pressure steam and the temperature at which the feed water enters the high-pressure evaporator. For example at 110 at. (1 564 lb.) the volume of steam to be circulated is the following multiple of the volume of saturated steam :

	Steam temperature	
	400° C. (752° F.)	500° C. (932° F.)
Feed water temperature 200° C. (392° F.) . .	5.3	4.2
Feed water temperature 300° C. (572° F.) . .	3.5	2.9

Hence at 110 at. (1 564 lb.), steam temperature 480° C. (896° F.) and feed water temperature 280° C. (536° F.) the ratio is 3.2 and therefore at a volumetric efficiency of 90 %, one pump can deal with 77 % of full load at 350 r. p. m.

b) Feed pump.

With a volumetric efficiency of 93 %, a water temperature of 200° C. (392° F.)

(1) *Zeitschrift des VDI*, vol. 70 (1926), p. 1971.

and a speed of 350 r. p. m., one pump deals with 85 % of the full output. The feed pumps are thus made about 10 % on the large side in order to utilise the storage capacity of the boiler.

c) Make-up pump.

This delivers about 7.2 % of the full output. Power taken : When both pumps are running at the same speed the power taken by each composite unit, at full load, is as follows :

Circulating pump	49 H. P.
Feed pump	27 —
Make-up water pump . .	0.2 —
Friction losses	14 —
	90 H. P.

The locomotive mechanism.

The design of the motion can be seen in figures 2 to 7. The low-pressure cylinder, which is constructed on conventional lines, has an inside drive on to the first of the coupled axles. The two high-pressure cylinders drive the second coupled axle, and therefore had to be designed entirely anew. The cylinder itself is machined from 60.11 steel, and is fixed to a cast-steel frame by a flange in front so that it is free to expand towards the rear.

The stuffing boxes are based, with appropriate modifications, on the design used successfully on low-pressure engines (1). Nine rings, figures 31 to 34, have been used in order to provide adequate tightness against the high working pressure. The four inner elements, which are subject to the greatest wear, have pressure oil lubrication. Wet steam and condensate are drained behind the foremost of the remaining five rings which complete the packing.

Experimental work on the piston rings is still in progress.

The principle of using thin and wide rings has been adopted, 3.5 mm. (0.138 inch) thick, and 8 mm. (0.315 inch) wide.

Relief holes from the bottom of the ring grooves connect to the adjacent inter-ring space in order to reduce the pressure as much as possible. The clearances are 9.15 % at the front end and 8.63 % at the rear end.

The valve gear.

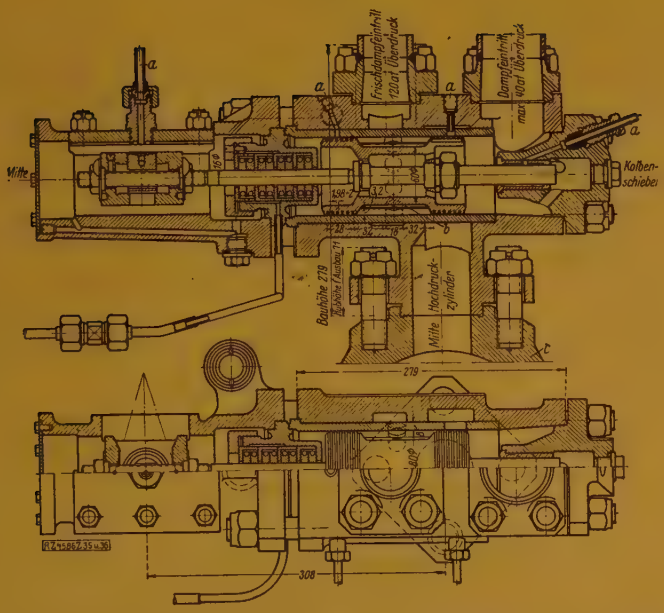
Thorough preliminary investigations were necessary to determine the design of the steam distribution arrangements The object in view was to use, if possible, the piston type of valve which has given such uniformly satisfactory results at low and medium pressures.

It appeared from the experiments that thin, wide rings gave the best results as regards steam tightness, since the loss at full load was only 2 %. Moreover, since this steam does work not only in the low-pressure part of the engine, but also in the high-pressure part during expansion, it was concluded that the piston type could be utilised for high-pressures and temperatures of the order in question, especially as there was no sign of excessive wear.

The piston valves were however designed as separate units for each end of the cylinder, figures 35 and 36; the considerations which led to this were the expansion of the cylinders as a whole, the use of 60.11 steel, and the desire to keep the clearances as small as possible.

A Heusinger (Walschaerts) gear is used, the valves being actuated by a vertical shaft carried above the cylinder.

(1) *Zeitschrift des VDI*, vol. 70 (1926), p. 1797.



Figs. 35 et 36. — High-pressure piston valve for cylinder of locomotive.

a = Lubrication. *b* = Sheet metal liner and hollow space for protection against high temperature. *c* = High-pressure cylinder.

Explanation of German terms :

Bauhöhe... = Height, 11 inches. — Dampfeintritt max. 40 *at* Überdruck = Inlet for max. 570 lb. per sq. inch steam. — Frischdampfeintritt 120 *at* Überdruck = Inlet for live steam (1706 lb. per sq. inch). — Hubhöhe f. Ausbau... = Height required for withdrawal (2 $\frac{13}{16}$ inches). — Mitte Kolbenschieber = Centre line of piston valve. — Mitte Hochdruck Zylinder = Centre of high-pressure cylinder.

Lubrication of the locomotive is carried out on exactly the same lines as on the standard locomotives.

Operation.

Apart from the internal processes, the operation of the locomotive is no different from that of an ordinary engine. The small size of the fire grate for the output renders it even easier.

The rate of steaming is adjusted to the load by regulating the speed of the circulation pumps, and the feed. When the demand for steam ceases at short notice, a by-pass valve allows part of the heat from the high-pressure steam to be transferred to the low-pressure boiler until the fire is damped. Similar action occurs at starting up, for which purpose steam is required from an external source, since the high-pressure circuit is heated directly from the furnace, the low-pressure boiler must be heated up by using the bye-pass.

Future development.

In addition to the constructional and operating advantages acknowledged to re-

sult from the application of the Loeffler principle to the locomotive, there is a prospect of deriving further benefit from giving up the low-pressure system that is now used. As it is only steam that circulates in the directly heated system, the use of perfectly clean water has no special signifiance, provided that a preheater can be designed to be easily cleaned.

Further development should result in a considerable simplification of the whole design with the important advantage of reduced capital and maintenance costs. The safest design was adopted for the first experiment, and the possibility of reconstruction for simpler systems of working was kept in mind. The multiplicity of parts must therefore be attributed to the experimental character of the engine; simplifications will undoubtedly be made.

The system that will eventually be adopted will depend upon the exhaustive tests to which the locomotive is to be subjected (1).

[625. 143. 2 & 669. 1]

The heat treatment of rails.

(Editorial, *The Railway Engineer.*)

It is somewhat paradoxical that one of the least permanent parts of the railway should be the so-called « permanent way ». Furthermore, with every increase in the weight, the speed and the frequency of traffic, so the deterioration of the track components increases in rapidity, and the period between successive renewals is shortened. Particularly is this the case with rails. Annually British railways purchase between them nearly 250 000 tons of steel rails, the vast majority of which are required to replace rails which have worn down under traffic until no longer fit for service. The annual value of these purchases amounts, at present prices, to roughly two million pounds sterling; and but a moderately increased resistance to abrasive wear, even if this necessitates a low additional cost, would effect an ultimate saving of a substantial sum in the purchase of rails, apart from the saving brought about by less frequent relaying operations. Unfortunately, however — as was made clear by the editorial article in the February issue, entitled « Steel Rails Past and Present » — the wearing capacity of the type of rail generally in use has not increased *pari passu* with the gradual increase in the punishment to which it is subjected. Conversely, it is generally admitted that the resistance to abrasion of steel made to the present-day B.E.S.A. rail specification and under modern manufacturing conditions is not the equal of that produced during the last two decades of last century.

At last, however, the inadequacy of modern rail wear — to which we have often referred in these columns — is beginning to arouse the attention that it merits. One of the factors which has brought it more urgently under review is the spread of railway electrification, which, with intensive train services, ra-

(1) See *Berichte der Zweiten Weltkraftkonferenz* (Proceedings of the Second World Power Conference), vol. 17, *Energiewirtschaft im Verkehrswesen* (Power Economy in Traction Engineering), Berlin, 1930, Publishers-VDI.

pid acceleration and constant braking, small-diameter driving wheels and non-spring borne motor loads, has made the problem of rail wear far more serious than before. Relief is being sought in three different ways. First of all, in the matter of analysis, the high carbon contents from which so much was expected (particularly in America), in better-wearing quality resulting from the increased hardness so obtained, have proved — as argued in the editorial article of February — worse than useless for the purpose intended. But the neglected claims of manganese as a wear-resisting constituent are at length recognised, and the 1 % manganese content now standardised in the London & North Eastern Railway rail specification, and under trial by other users, is a valuable step in the right direction, as it is practically certain to give a measure of increased wear without any increase in the cost of the rails so manufactured. In the second place, there are various alloys favoured, but to a limited extent only, as here the matter of cost in relation to service rendered is a serious consideration. The most effectual for the purpose — manganese alloy, containing from 12 to 14 % manganese — costs, for example, from five to six times the price of ordinary steel, and such rails are therefore ruled out of court for any but locations subject to the most exceptional of wear. Limited use is made of nickel and chromium as alloys, but in regard to these the opinions of engineers are notoriously divided as to their merits, and chrome-steel in particular has none too good a reputation for reliability.

The third alternative is that of heat treatment, with a view to securing in the rail-head the structural condition best fitted to withstand abrasive wear. That condition is sorbite — midway in the structure range between the soft pearlitic and the glass-hard and exceedingly brittle martensitic condition — and it is the maximum combination of hardness and ductility that can be obtained. The development of a process for applying on a commercial scale suitable cooling after rolling, to achieve this result, has been the work of Messrs. Sandberg — the well-known consulting engineers — and the gradual evolution of the idea and its present application are described elsewhere in this issue. The most important feature of the methods now in use is the exactness of temperature control throughout the application of the treatment; each rail is treated individually, and the condition aimed at can be guaranteed with practical certainty in every case. It is customary to obtain a rise averaging 10 tons per square inch in the tensile strength of the head of every rail treated; and with the retarded cooling now applied at the plant described in the article, the original percentage of extension is maintained unimpaired, so that ultimate tensile strengths of 60 to 64 tons per square inch, with 16 to 14 % extension, are becoming common at the works in question. Similarly, a rise of 40 to 60 points in the Brinell hardness number, as a result of the treatment, is normal, and these tests reveal that the average depth of penetration into the rail-head is at least 5/8 to 3/4 in. Quotations are given from various reports, which show that rail life has increased in some cases by over 100 %. Of such importance is this development regarded by British railmakers that to the two up-to-date treating plants on Tees-side another is being added, in West Cumberland, while similar developments are taking place in America. The Sandberg treatment, with its modern methods of application and exactness of control, may prove, indeed, to be the most effective and economical solution of the rapid rail wear problem that has yet been evolved.

[625. 143 2 & 669. 1]

The modern application of the Sandberg sorbitic rail treatment,

by Cecil J. ALLEN, M. Inst. T.

Figs. 1 to 8, pp. 949 to 857.

(From *The Railway Engineer*.)

I. — The nature and method of treatment and some test and wear results.

Before entering upon the present-day method of applying the Sandberg sorbitic treatment to rails, it is necessary briefly to review the considerations which underlie the treatment. The physical properties of steel are subject to wide variations, both as a result of varying the percentage of carbon contained in the steel, and also of the varying heat treatments to which the steel is subjected. Increase in the hardness of the steel is obtained by increasing the carbon content, but recent research is making it abundantly clear that, so far from improving the capacity of the steel to resist abrasive wear, increased hardness so obtained tends to reduce the wearing capacity when such steel is rolled into rails. Further, such additions to the carbon content of the steel progressively reduce its ductility and resistance to shock, so much so that the point is reached at, say, 0.75 % carbon or slightly over, when this weakened resistance to shock becomes, in the case of the steel rail, a menace to safety. But suitable heat treatment, on the other hand, places at the disposal of the user a wide variation in physical properties for any one given carbon percentage — a greater variation, indeed, than that secured by varying the carbon content — both with medium and high carbon steels. Exceedingly hard and dangerously brittle conditions in the steel can be reached by violent quenching, but the aim of the Sandberg sorbitic treatment is to arrive at a physical condition in which, without the use of any excessive percentage of carbon, the steel is at its maximum of tenacity and ductility, and in this way best fitted to withstand the abrasive action of the wheels when passing over the rails. This condition is known as sorbite.

In its structure steel is crystalline; the carbon content is responsible for the nature of the crystals, while the final crystalline structure is determined by the heating and final rate of cooling of the steel. In a medium carbon steel which has been cooled at a normal rate, the ferrite, which is the iron proper, and the cementite — a chemical combination (iron carbide) of the carbon present with a certain proportion of the iron — crystallise out in alternate layers, the resulting structure being known as pearlite; free ferrite, or iron left in excess from this distribution, crystallises round the pearlite. But in a high carbon steel it is the cementite which is in excess rather than the ferrite, and free cementite crystallises round the pearlite in such a steel, rather than free ferrite. On being heated up to a temperature above what is known as the « critical range » — about 720° to 750° C. in the case of a steel of this character — the ferrite and

cementite pass into what is known as a « solid solution », and gradual cooling down through this stage results in the steel recrystallising to its original pearlitic condition. But an acceleration of the cooling rate will arrest this crystallisation at stages in which the physical condition of the steel is completely altered. Violent quenching in cold water will retain the ferrite and cementite in solid solution, the resultant structure being known as martensite, which is glass-hard and extremely brittle. As the rate of cooling is slowed down, other types of structure are produced, the penultimate structure — before pearlite, which gives the maximum combination of softness and ductility — being sorbite, which affords, on the contrary, the maximum combination of hardness and ductility for any given analysis. The sorbitic range is therefore aimed at in the production of steels which are to be subjected to shock or to an exceptional degree of wear; and the Sandberg treatment has been evolved to produce this condition in the head of the steel rail.

The problem in applying such a treatment in the case of the rail is that of mass handling. In the treatment for the same purpose of such items as gun forgings, for example, individual attention is a comparatively simple matter. But in the treatment of rails, each unit — a rail from 45 to 60 feet long — is brought to the apparatus at a frequency which may reach 60 to the hour, and if the cooling is to be arrested at the precise point at which the sorbitic structure is attained and uniform results are to be obtained, even application of the cooling medium to the rail-head and accurate control of temperature are both vital. At the same time, whether the whole or a part only of each rolling be treated, the mill output must not be slowed down, neither must the treatment require the erection of costly new plant, which would unduly increase the cost of the rails so treated. The stages by which the present-day application of the sorbitic rail treatment has been brought by Messrs. Sandberg to reliability and commercial success, within the narrow limitations mentioned, are therefore of no small interest.

Early sorbitic rail experiments.

The first experiments in the production of sorbite in rails were made by the late Dr. J. E. Stead, the wellknown metallurgist, of Middlesbrough, in conjunction with Mr. Windsor Richards, a Teesside steelworks manager. Believing that the excellent qualities of oil-quenched steel might also be produced in rail steels, if the latter were brought to the same condition by suitable treatment, they treated a number of 5-foot lengths of rail with success by dipping in water, the loss by abrasive wear, as nearly as could be measured, being in the proportion of between 33 and 80 to 100 in favour of the treated rails. But attempts to treat 30-foot rails resulted in such distortion that the experimenters were unable to bring their ideas to commercial success. The matter was then taken in hand by Messrs. Sandberg, who perfected their process in the early part of the war, and patented it in 1915 and 1916. It was at the now defunct Leeds Steelworks that the initial experiments were made by blowing steam on the heads of tramway rails, while they were still in their hot condition after having been hot-sawn to length, to increase the rapidity of their cooling through the critical range of temperature. This treatment having given successful results, a plant was laid down at the Dowlais Works of Guest, Keen & Nettlefolds Limited, in order to apply cold dry air, at a pressure of 7 lb. to 10 lb. per square inch, to the rail-heads for the same purpose. Following the fusion of this firm with Baldwins Limited, under the title

of the British Steel Corporation, the Dowlais plant has gone out of use also, though a similar plant erected at the Steelton, Pa., works of the Bethlehem Steel Corporation of the U. S. A. is still working. The objection to both steam and dry air, however, is that they are too slow in action, and that by their use mill output is unduly slowed down; a more rapid but equally controllable cooling medium had therefore to be evolved.

This medium has been found by Messrs. Sandberg in a combination of very finely atomised water with the air, the resultant product being more correctly designated « moist air » than a combined air-blast and water-spray. Colloquially the product is generally known as « Scotch mist ». The details and control of its application have now reached a high degree of perfection, so much so that the desired sorbitic condition of the rail-head in treated rail is absolutely assured. The first such plant was laid down at the Cleveland Works, Middlesbrough, of Bolckow, Vaughan & Co. Ltd. (now amalgamated with Dorman, Long & Co. Ltd.), and with various modifications designed to improve its working, this plant is still in use constantly. The equipment consists of a box girder spanning the hot-bank at a point adjacent to the hot-saw; the girder is divided into two parts longitudinally, one acting as a reservoir for water, and the other for air, which is compressed by a motor-driven fan at one end of the girder. All rails as they are cut at the hot-saw are skidded under the apparatus as they pass across the hot-bank; and those for treatment are arrested by hydraulically-operated legs and lifted up to the apparatus, where a blast of cold air is directed on to the head of the rail by means of patent nozzles arranged 2 1/2 inches apart along the full length of the girder. The cooling effect of each nozzle is accelerated by means of a finely-divided water-spray, atomised by the action of the compressed air on a water-jet of but 1/16-inch diameter, so that the amount of water actually used is negligibly small. Accurate pyrometric control of temperatures is provided, as also of duration of treatment. This plant is capable of treating one-half of the total output of the rail-mill, and has given good and reliable results throughout its service.

The latest methods of treatment.

A more recent installation is that at the works of the Cargo Fleet Iron Co. Ltd., at Middlesbrough. In this case also the treatment was at first made by means of low-pressure dry air, but owing to its slowness of action moist air treatment was shortly substituted, and the plant, located at the end of the main roller-train from the rail-mill, beyond the hot-saw, was doubled in length. The result is that when required the complete mill output can now be sorbitically treated, the Cargo Fleet plant being the only one in the world as yet of 100 % output capacity. Another important development at the Cargo Fleet works has been the application of retarded cooling to the rails after the sorbitising treatment is complete, by means of a specially-designed oven. The principles on which this additional treatment has been based are dealt with fully in the second part of this article, but in the meantime it may be stated that the object of the oven is to even out the widely-varying internal and external temperatures of the rails, as they cool through a certain predetermined temperature range, thus preventing the development of certain harmful internal stresses, particularly in the rail-heads. The oven has now been in constant operation for about two years, during which time it has dealt with a considerable tonnage of both treated and untreated rails. Not only has its application given satisfaction in preventing the for-

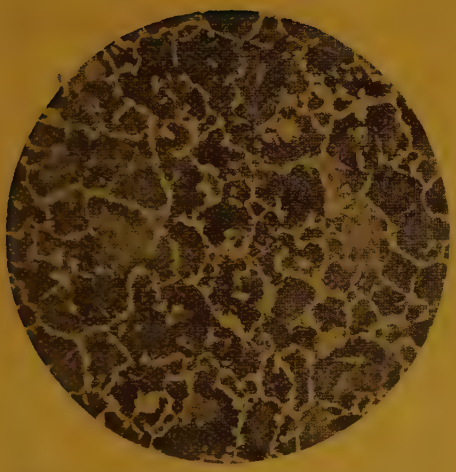


Fig. 1. — Pearlitic structure of untreated rail.

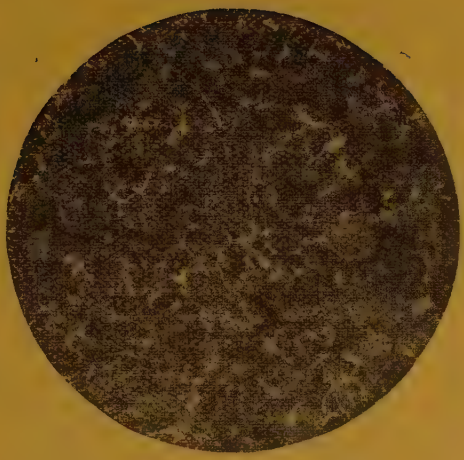


Fig. 2. — Normal sorbitic structure.

(+ 75 diameters).

mation of dangerous internal fissures in the rail-heads during cooling — which prevention is the primary object of the retarded cooling — but it has also had very beneficial effects on rail-straightening.

The present reliability of the Sandberg sorbitic treatment is largely the result of the accurate methods of temperature and time control which have been developed since the days when the treatment was in the experimental stage, and results were more or less uncertain. At the Cargo Fleet Iron Co.'s works the control gear is concentrated in a small building adjacent to the treating plant. Optical pyrometers fixed in suitable positions adjacent to the roller-train take the temperature of the rolled-out rail as it reaches the hot-saw, and the temperature of each rail at the appartus, both before and after treatment, these temperatures being read by electrical means in the control-house. Directly the air-blast is turned on, a hand begins to move round a large dial, recording in seconds the duration of the treatment; this is varied in accordance with carefully-calculated tables, based on the cross-sectional area of the rail-head, the percentage of carbon and manganese in the steel, and the exact temperature at which treatment is begun. The finishing temperature is checked by the fixed pyrometers, as well as by an ingenious appliance which drops on to the rail-head certain chemical salts fusing at different temperatures, so giving a certain indication as to whether or not the finishing heat is within the required range. Messrs. Sandberg's representatives are present whenever treatment is being carried on, and each rail thus receives individual attention. Falling weight, tensile, impression and Brinell tests are afterwards carried out on representative rails, to check the efficiency of the treatment and the depth of penetration into the rail-head.

Some test results.

In the tables I-III details of some typical tests are given. The casts concerned were three of 70-lb. and one of 80-lb.

Table I. — Chemical analyses.

Cast.		Rail section.		Makers.	Analysis.				
Reference letters.	Works No.	Weight.	Type.		Carbon	Silicon.	Sulphur.	Phosphorus	Manganese.
		Lb. per yard.			*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
A	30	70	Flat-bottomed.	Dorman, Long & Co. Ltd.	0.54	0.12	0 036	0.034	0.75
B	38	70	—	— —	0.59	0.12	0 038	0.026	0.72
C	42	70	—	— —	0.57	0.11	0 038	0.034	0 78
D	54	80	—	— —	0.60	0.11	0.035	0.037	0 76
E	762	95	Bull-head.	Cargo Fleet Iron Co. Ltd.	0.61	0.10	0 040	0.032	0 80
F	158	96	Flat-bottomed.	— —	0.63	0.14	0.045	0.037	0 78
G	201	96	—	— —	0.59	0.15	0.036	0.030	0.78

Table II. — Tensile test results.

Cast reference letter.	Falling weight test.		Tensile test.				Impression test.	Notes.
	Height of drop.*	Deflection.	Ultimate strength.	Rise by treatment.	Extension in 2 inches.	Reduction of area.	50-ton load on 19-mm. ball.	
	Ft. In.	*Inches.*	*Tons per sq. in.*	*Tons per sq. in.*	*Per cent.*	*Per cent.*	*Depth in millimetres.*	
A	17 6	3.65	49.6	10.4	22.0	39.2	3.95	Untreated.
—	—	*3.10*	*60 0*		*12.0*	*24.8*	*2.80*	*Treated.*
B	—	3.30	51.2	11.6	18.0	27.6	3.70	Untreated.
—	—	*2 90*	*62 8*		*11.0*	*24.8*	*2.60*	*Treated.*
C	—	3.50	50.8	8.4	20.0	33 6	3.60	Untreated.
—	—	*3.05*	*59.2*		*13.0*	*27.6*	*2.80*	*Treated.*
D	22 0	3.60	53.6	10.0	20.0	30.8	*3.65*	Untreated.
—	—	*3.20*	*63.6*		*13.0*	*27.6*	*2 80*	*Treated.*
E	20 0†	3 05†	50.0	11.9	14.5	30.8	3.55	Untreated.
—	—	*2.70††*	*61 9*		*15.0*	*29.9*	*2.70*	§*Treated.*
F	25 0	2.60	53.6	10.0	17.5	28.0	3.50	Untreated.
—	—	*2.40*	*63.6*		*15.5*	*30.8*	*2.70*	§*Treated.*
G	—	2.55	51.6	9.2	16.0	28.0	3.50	Untreated.
—	—	*2.30*	*60.8*		*14.5*	*30.8*	*2.60*	§*Treated.*

Deflection under first drop of 7 ft : † 0.92 inch. — †† 0.70 inch. — * 1-ton tup in all cases. — § Retarded cooling in oven after treatment.

TABLE III. — **Brinell hardness tests.**

Cast reference letter.	Untreated or treated.	Hardness numbers in positions as under (see fig. 3).									
	Position:	1	2	3	4	5	6	7	8	9	10
A	Untreated.	207	207	197	201	207	192	212	201	201	207
—	*Treated.*	*269*	*285*	*269*	*269*	*262*	*255*	*269*	*255*	*212*	*217*
B	Untreated.	212	212	212	217	217	217	223	212	217	217
—	*Treated.*	*277*	*277*	*269*	*262*	*262*	*241*	*255*	*255*	*223*	*223*
C	Untreated.	212	212	212	212	217	212	217	201	212	217
—	*Treated.*	*248*	*262*	*255*	*248*	*248*	*229*	*241*	*229*	*217*	*217*
D	Untreated.	223	223	223	217	223	217	241	223	235	241
—	*Treated.*	*262*	*269*	*269*	*255*	*262*	*241*	*255*	*248*	*228*	*228*
E	Untreated.	223	223	223	223	223	217	217	223	207	241
—	*Treated*.*	*277*	*285*	*277*	*269*	*277*	*248*	*255*	*255*	*235*	*235*
F	Untreated.	223	223	223	223	223	217	223	217	212	229
—	*Treated*.*	*277*	*277*	*277*	*269*	*269*	*248*	*255*	*248*	*229*	*220*
G	Untreated.	223	223	207	223	207	223	212	201	201	223
—	*Treated*.*	*269*	*277*	*262*	*269*	*255*	*248*	*277*	*248*	*229*	*217*

* Retarded cooling in oven after treatment.

flat-bottomed rails at the Cleveland Steelworks of Dorman, Long & Co. Ltd., and one of 95- lb. bull-head and two of 96-lb. flat-bottomed rails at the works of the

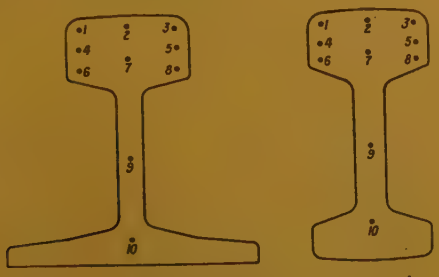


Fig. 3. — Brinell test points on flange and bullhead rails.

Cargo Fleet Iron Co. Ltd. There will first be noticed the characteristic rise in the tonnage of the tensile test, ranging from 8.4 to 11.9 tons per square inch and averaging 10.2 tons, while the percentage of extension on a 2-inch gauge length was in no case less than 11 %. The salutary effect of the retarded cooling in the oven at the Cargo Fleet Works may be seen in the remarkable fact that, although the average of the three Cargo Fleet tensile tests rose from 51.5 to 62.1 tons per square inch, yet the percentage of extension merely changed from an average of 16.0 to one of 15.0 % — a proof that the oven treatment maintains the original ductility of the steel while in no way affecting the hardness which has been produced by the sorbitic treatment. As regards freedom from brittleness, the normal falling weight tests for these rail sections were in all cases sustained without fracture. Finally, the Brinell tests, taken over the polished face of the rail section, reveal the fact that the treatment has not merely a surface effect, but can be relied on to penetrate downwards through the head to a depth of from 5/8 to 3/4 inch. The working control of the process has now, indeed, been reduced to so fine an art that a rise of 10 tons per square inch and over in the tensile breaking strength of the steel, as a result of the treatment, is normal,

together with an increase of from 40 to 60 points in the Brinell hardness number.

To the end of September 1930, the total tonnage of rails sorbitically treated in Great Britain, France and the United States by the Sandberg process amounted to 57 446 tons for railways and 68 975 tons for tramways, now in use in all parts of the world. As a result of successful wear results with a small trial order, orders for no less than 16 000 tons of sorbitically-treated rails have recently been executed for the railways of the Union of South Africa. Important wear comparisons between many of these deliveries and rails of ordinary steel quality are already to hand, despite the comparatively short period during which the Sandberg process has been commercially available, and some of these results may now with advantage be mentioned.

Wear of sorbitic rails abroad.

In the *Bulletin of the International Railway Congress Association*, vol. XI, Nos. 8 and 10 (August and October 1929), the replies of various railways were given to a questionnaire as to their experience with rails which had been rolled from special steels, or heat-treated. The New South Wales Government Railways reported 95 % greater loss of weight by wear with ordinary rails than with a trial order of Sandberg sorbitic rails, despite the fact that the carbon content of the latter was only 0.58 %, as compared with 0.64 % in the ordinary rails. Tests were made by the Victorian Railways of Australia in a curve of 15 chains radius, carrying heavy traffic, the three years' life of ordinary 100-lb. flat-bottomed rails at this location being increased to all but five years by the substitution of Sandberg sorbitic rails, the loss by weight in this case being 65 % greater in the former case than in the latter. Similarly favourable reports from the railways of the Union of South Africa, France and Japan were published in the same issue of the *Bulletin*, and led to a recommendation by the International Railway Congress Association that railways should use « rails which have received suitable heat treatment on sections of line where the rails are subjected to exceptional stresses, to skidding and to repeated braking, rails so treated resisting the propagation of superficial fissures (cracks in the running surface) better than rails which have not been so treated ».

Experience with Sandberg sorbitic rails in the United States has been similar, though in many cases the reduction in wear has been still more marked. It is by no means improbable that this exceptional increase in the life of American rails after treatment is influenced by the abnormally high carbon percentages worked to in present-day American rail analyses. As mentioned earlier, modern research is tending emphatically in the direction of lower carbon and higher manganese contents in rails; for example, in the *Bulletin of the International Railway Congress*, No. 6, June 1930, the Vice-President of the Permanent Way Materials Specification Committee of the Belgian National Railways expresses definite disapproval of raising carbon percentages with a view to increasing rail wear, maintaining that the surface layers of high carbon rails perish through successive erosions, rather than work hardening with the passage of traffic, as do softer and better-wearing rails. In many of the American sorbitic rail experiments, however, lower carbon contents were worked to than in the comparison rails, so that the sorbitic rails stood to gain both as a result of their lower carbon percentages and of their treatment.

As a result of these and many other successful tests, the American Electric Railway Association has drawn special attention, in a report made in 1929 by

its Way and Structures Committee, to what it describes as the « Surface hardening of rails » by the Sandberg process, and to the fact that an increase in Brinell hardness of over 50 points can be relied on by the application of this treatment, with correspondingly beneficial wear results. It seems clear, therefore, that the Sandberg sorbitic rail, at a cost to the user which at present exceeds the cost of ordinary steel rails by a bare 25 %, is well worth consideration for all track locations where the wear of rails is rapid.

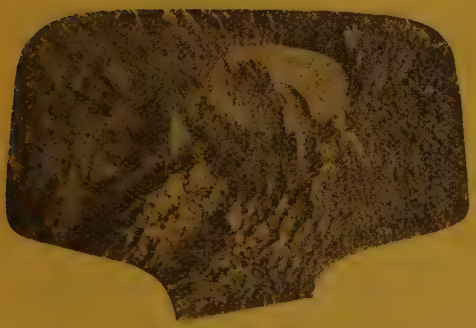


Fig. 4. — Typical internal fissure in rail.

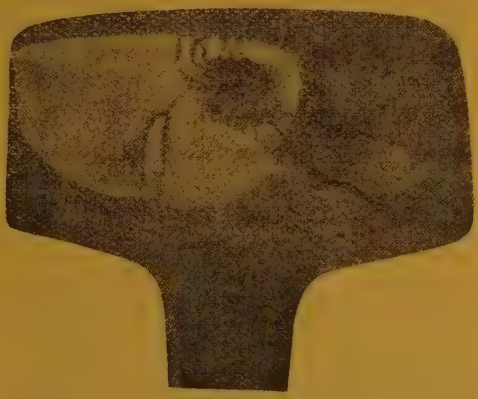


Fig. 5. — Another interual fissure, showing extension from nucleus.

gineer there appeared an article entitled « The menace of the transverse fissure in railway rails », in which there was reviewed the report of the Director of the American Bureau of Safety to the Interstate Commerce Commission on a serious derailment which occurred at Onley, Virginia (1), clearly caused by a rail fracture. This, in its turn, was traced to the presence in the rail-head of a transverse fissure defect, which had gradually spread under the influence of the traffic until the rail had broken through. The report proceeded to discuss the dangerous prevalence of the transverse fissure in American rails, mentioning the fact that no fewer than 36 000 such rails suffering from a fissured condition of the head had been removed from American railroads up to January, 1930, and that a special travelling apparatus had been devised to detect *in situ* the presence of the defect, so that the rails might be taken out of the track before casualties to trains were caused by their breakage. No such general trouble has ever been experienced in this country, but at the same time the transverse fissure — known coloquially in British rail-mills,

(1) See also *Bulletin of the Railway Congress*, July 1931, p. 649.

II. — The oven method of retarded cooling.

In the first part of this article, reference was made to the retarded cooling which, at the Cargo Fleet Iron Co.'s Middlesbrough works, follows the application of the Sandberg sorbitic treatment to rails, and is carried out in a specially designed oven through which the rails are passed on their way to the cooling bank proper. The line of research which has led the patentees of the oven to evolve and perfect this post-sorbitising treatment has been one of great interest. In the September 1930, issue of *The Railway En-*

from its characteristic appearance, as « grey spot » — is by no means an unknown defect here in Great Britain and on the Continent. The possibility of such fissures in rails which had undergone the Sandberg sorbitising treatment, and particularly rails from casts containing a high percentage of carbon, led Messrs. Sandberg to perfect their oven treatment with a view to arresting, at the outset, any tendency of the steel to so fissure. The results of their research have been so successful that the application of this retarded method of cooling, whether to sorbitised or to untreated rails, may well prove to be one of the most important discoveries bearing on rail manufacture that has been made during the past few decades. The line of research leading to the evolution of the oven may now be set out in detail.

The nature of internal fissures.

By breaking through a rail which is suffering from the fissure defect, it may be seen that the defect consists of a fine hair crack, generally at right angles to the length of the rail — whence the American designation of « transverse fissure » — but occasionally longitudinal or oblique in its location. It is usually in the lower part of the head, and, when exposed by fracture, is revealed as an approximately circular patch varying in size from the microscopical to a diameter of 1/2 inch or more, and having a silvery appearance which differs from that of the remainder of the fracture. This has given rise to the British name of « grey spot ».

Microscopically the defect appears as exceedingly fine cracks running round rather than through the crystal grains of the steel. The occurrence of similar internal defects is not unknown in other steel products, and particularly in alloy-steel forgings, where from their characteristic appearance these fissures have been nicknamed « snowflakes ». Statistics relating to American rail failures have proved that certain casts of steel have produced far more transverse fissure defects than others, and also that the defect is existent in rails before they have been laid in the track at all. This clearly indicates that track conditions, though they may and do cause that development of the fissure which finally results in breakage of the rail, are not responsible for its formation. Another result of research has been to prove that transverse fissure defects occur chiefly in high-carbon steels (with over 0.60 % carbon), or in alloy steels, both of which are characterised by the absence of a continuous network of free ferrite. Starting with the assumption that the « shattered zone » of the rail-head was jointly the product of carbon content and manufacturing methods, therefore, Messrs. Sandberg set out to discover the exact conditions producing the fissures, and how these conditions might be modified in such a way as to overcome this dangerous fissure-producing tendency.

A transverse fissure in a new rail — that is, before running over the rail has caused the weakness to extend — is, as previously mentioned, roughly circular in shape. This definitely limited its formation to a period subsequent to rolling, as if formed prior to rolling the pressure of rolling would cause it to take up an elongated or otherwise distorted shape. It has also been mentioned that the cracks pass round the crystal grains of the steel, and this further defined the cracking as taking place at a temperature above 300° C., seeing that below that temperature fracture of steel invariably takes place through, rather than round, these grains. Again, if the cracks were produced at a temperature above the critical range, they would necessarily be found as a boundary to the new crystals produced within the critical range. As this type of structure did not obtain, however, it was ap-

parent that the cause of the fissuring must be looked for at a temperature between the critical temperature of the steel, as its upper limit, and a lower limit of about 300° C. This obviously directed attention to the period during which the rails are cooling out, and to the physical changes which take place at the same time, and are known to be of a singularly variable character.

In the *Journal of the Iron and Steel Institute* (No. 2) for 1921, there were published some curves, in which the investigator Dupuy represented graphically the changes in physical properties, at different temperatures, of two steels containing respectively 0.91 % and 0.55 % carbon. The tensile strength of both steels tended to increase up to a temperature of between 320° and 350° C., after which it fell rapidly; the ductility curves showed that the elongation percentage, after a slight fall at about 250° C., rises rapidly up to 430° C., falls to a temperature of 550° to 580° C., and finally begins again to rise. The reverse series of changes was found to take place on cooling the steel from a high temperature. These results led Messrs. Sandberg to make a new investigation, somewhat on the same lines. A cast of steel was chosen with a carbon content of 0.82 % and a manganese content of 0.71 %. Prepared bars were bent slowly at different temperatures up to 600° C. in a Humfrey notched bar test machine, and curves were then plotted to represent the maximum bending moment withstood by the specimens and the angle through which they bent before fracture. The maximum bending moment was found to fall up to a temperature of 150° C., to rise rapidly to a maximum at about 380° C., and then to fall very rapidly indeed up to the maximum temperature at which the tests were carried out. A very similar curve was obtained by plotting the angle bent through before fracture, save that after falling rapidly from 400° to 500° the angle increased as the temperature rose further. The most unstable condition of the steel when cooling was therefore demonstrated to be at a temperature somewhere between 350° and 500° C., and it seemed clear that the conditions favouring the development of the transverse fissure must be looked for within that range.

Critical temperatures in cooling.

It is at a temperature of between 800° and 1 000° C. that the rails leave the rolls, well above the critical temperature at which their crystalline structure is formed. As they lie on the cooling bank, after being sawn to length, their temperature gradually falls, but all portions of the section do not cool at a uniform rate. The rails lose heat by radiation from their surfaces, and portions of the interior lose heat by conduction to other parts of the section. Conditions must, therefore, arise during the cooling when interior portions of the rails are still at a temperature of 500° C. or so, while the exterior portions have reached a lower temperature of, say, 400° C. That is to say, while the inside of the rail is still weak as regards strength and ductility, the outside is strong and more ductile. If the inside is then losing heat more rapidly than the outside is cooling by radiation, the steel must be subjected to severe internal strains in consequence, and such strains are far more pronounced in character than any set up by the general temperature differences between the various parts of the section, as for example, the head, web and foot. The strain is further accentuated by the sudden and rapid increase in strength in a steel which is cooling, reaching its maximum, as already explained, at a temperature of about 370° C. Yet another result of investigation which directed attention towards the cooling conditions was the fact that internal fissures were less prev-

Fig. 6. — End view of oven for retarded cooling of rails, Cargo Fleet Iron Campany's Works, Middlesbrough.

Fig. 7. — View showing 80-lb. flange rails after passing through oven. Cold straightening has yet to be carried out, but is greatly reduced in degree as a result of the retarded cooling.

alent in American rails which had been rolled during hot weather than with those rolled in the winter. Messrs. Sandberg therefore came to the conclusion, which in the circumstances it seems impossible to avoid; that the formation of the transverse fissure occurs during the cooling of the rail, and that the physical changes just described are the factors responsible. Dangerous internal strains in the steel, they became convinced, could no longer be set up if the differences of temperatures between the interior and exterior of the rail could be evened out, by some retarded method of cooling applied through this range.

The oven now evolved by Messrs. Sandberg and the Cargo Fleet Iron Co. Ltd. has been designed to attain this desirable result. It is a cover which completely spans the hot-bank, so as to receive the longest rails rolled. It consists of two lattice-steel booms supporting an arch of about 7 feet in width and 9 inches thick, composed of special refractory bricks of light weight. Immediately after the sorbitising treatment the rails, now at an external temperature of 550° to 600° C., are passed through hanging shutters into the oven, the internal temperature of which is maintained by their own heat, increased as may be necessary — as, for example, at the commencement of operations — by the use of gas-jets. The actual time necessary to even out the temperature through the whole section of the rail is about 6 minutes, but as a matter of convenience the rails remain in the oven for 20 to 30 minutes, after which the entry of further rails on the inward side pushes out those whose cooling has been adequately retarded. From here they pass through a lean-to shelter, and thence on to the hot-bank to cool out in the ordinary way.

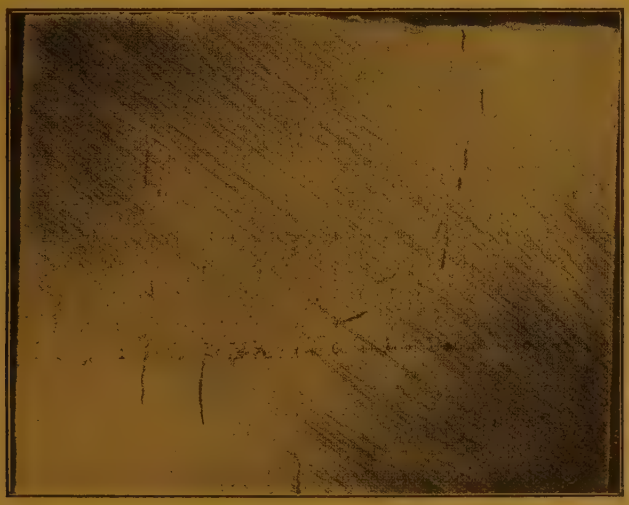


Fig. 8. — Longitudinal section of rail-head, shaving internal fissures.

The effect of oven treatment.

As mentioned previously, the oven has now been in constant operation for two

years, during which time it has dealt with approximately 20 000 tons of Sandberg sorbitic rails, in addition to a considerable tonnage of untreated rails. Careful experiments have confirmed beyond the possibility of dispute the relief of internal stresses by this retarded method of cooling. The same result could doubtless have been arrived at by slow cooling from the finishing temperature of rolling right down to the cold condition, by boxing or stacking the hot rails on the cooling bank, but such a procedure would be inadvisable; not only would it seriously slow down production, but it would cause growth in the size of the steel grains and cause a softening of the rails by annealing, of which there was no trace in the Cargo Fleet tests cited in the first part of this article. The object of this invention is, therefore, to check the loss of heat by radiation at a stage of the cooling when the interior and exterior portions of the rail are still above 500° C., but after the rail has passed through the critical range proper, so that the temperature becomes as uniform as possible throughout the rail section while it is cooling through the dangerous range from 500° down to 300° C. By this evening of the temperature as between the outer and inner portions of the rail, the internal strains which encourage fissures are reduced to so negligible a minimum that they no longer have a rupturing effect. Proof of this has been afforded in various ways. The experiments above referred to were conducted on 6-foot lengths of high-carbon rail, which were artificially cooled through the critical range proper (by the ordinary sorbitic process), and then, after normally cooling out, were sawn through in a longitudinal direction in such a way that the head, web and foot were separated from each other. The result was that the heads were drawn by internal strains into a camber of from 0.20 to 0.26 inches. Rails similarly treated, but retarded in cooling by being passed through the oven, showed a camber of 0.05 to 0.06 inch only. In the circumstances it is not surprising that the oven treatment results in much improved straightening of the rails. (fig. 7). Their condition is such that very little in the way of cold-straightening will be required, and this, of course, is all to the advantage of the rail. Loss of rails by breakage in cold-straightening has, in consequence, been materially reduced when they have been subjected to the oven treatment, and the primary object of eliminating the internal fissure appears to have been attained.

The oven need not necessarily be of a fixed type, but may consist of a movable arched cover, made of or lined with some suitable non-conducting material, arranged over the hot-bank. It is not until the rails have cooled to a temperature below the critical range that the cover is moved into position, say at a little above 550° C., and it remains in position until the temperature has fallen slowly to 300° C. By keeping the cover moving slowly across the cooling bank, provided that it has been designed to cover sufficient rails, or that more than one cover is in use at a time, the retardation of cooling can be made to keep pace with output. Where the rails have been cooled rapidly through the critical range by the Sandberg sorbitic treatment, described in the first part of this article, the problem is simpler; a fixed cover or oven can be employed — as at the Cargo Fleet Iron Co.'s works — and the rails passed direct to it without any preliminary cooling down towards 550° C. on the hot-bank.

In the cooling of a flat-bottomed rail section, as compared with a bull-head section, the stresses in the head are greatly increased by reason of the large area of the web and foot exposed to radiation, thus adding to the force with which this colder and therefore stronger part of the rail section pulls on the remainder. With the large flat-bottomed

rail sections in use in America this property, coupled with the excessively high percentages of carbon worked to — as has been so often stressed in these columns — has contribued to the dangerous prevalence on American railroads of the transverse fissure defect. Axle-loads in excess of 30 tons, and the hammer-blow on the track resulting from the dynamic effect of the heavy reciprocating and rotating parts of two-cylinder locomotives of great power, have then caused the extension of the fissures from their small nuclei in the rail-heads until frequent failures of rails have resulted. Apart from a drastic revision of the modern American rail analysis, which is of extremely debatable value from the wear-resisting point of view, the only safe solution of the American rail problem appears to be the application of retarded cooling to the rails, and in the circumstances it is not surprising, that the Sandberg oven method of applying such cooling is about to come into use at various American rail-mills, in particular the important Bethlehem Steel Company's plant at Steelton, Pennsylvania. Its application is not, as has just been shown, confined to rails whose cooling through the critical range has already been accelerated by the Sandberg treatment to arrive at a sorbitic microstructure, but all rails of high-carbon content stand equally to benefit. In this country its use is for the present confined to the works of the Cargo Fleet Iron Co. Ltd., at Middlesbrough, but the oven is being added to the existing sorbitising plant at the Cleveland Works of Dorman, Long & Co. Ltd., and plant for both the sorbitic treatment and the retarded cooling of rails is now being laid down at the Workington (Cumberland) branch of the United Steel Companies, while other installations are probable shortly. It is a development which may have far-reaching consequences. In particular it may put within the reach of the rail user compositions of steel which, though desirable enough from the wear-resisting point of view, have been denied to him because of the brittleness of the rails so manufactured, and the experimental activities of the patentees, directed thus in the first instance towards the curing of a dangerous defect, may well have a vital influence at the same time on the problem of rail wear.

[621. 43 (.43)]

Small internal combustion motor locomotives operating on the Reichsbahn (German State Railways),

by Fr. WITTE, Reichsbahnrat, and O. STAMM, Dip -Ing., Berlin.

Figs. 1 to 7. pp. 862 to 869.

(From the *Verkehrstechnische Woche*, Nos. 44 und 45, 1930.)

The unsatisfactory economic conditions that prevail generally have led the German State Railways to explore the possibilities of adopting improved operating methods in accordance with modern technical development, and of thereby securing increased economy in working. One result of this has been the continual trying out of improved and new designs in the case of steam locomotives, and their eventual adoption in service.

In the field of internal combustion motor locomotives, the Reichsbahn has departed entirely from the practice in other countries in regard to the transmission system (1). Their programme has expanded from Diesel units of 180, 250 and 400 H. P. with Lentz drive, to the use of Diesel-compressed-air locomotives of 1 200 H. P. (2). At the present time a particularly promising stage has been reached in the development of small motor locomotives.

It is characteristic of the steam locomotive that it can be replaced economically by motor units more easily in the small sizes than in the case of more powerful engines.

If steam locomotives of small size are employed, they must be worked very fully if they are to earn a return on the expenditure for wages, management and supervision. Hence it has always been the aim to concentrate locomotives at busy centres and to allow the work at medium and small stations to be done by the train engines working in the locality. This applies particularly to the handling of goods wagons at stations between the large transhipment depots, the train engines doing the whole of the shunting work in addition to working the trains. The stopping times necessitated by this arrangement have to be fixed with due regard to the maximum amount of shunting that may be required, and this naturally leads to a considerable lowering of the commercial speed of the freight trains. The individual shunting operations in such cases require only a small amount of power compared with that needed for train haulage, and therefore the use of these traction units, which are usually of a heavy type, is somewhat extravagant, although still cheaper than the allocation of a special main line locomotive for one or several stations. For a long time, there appeared to be no really satisfactory method of improving these conditions, particularly one which would meet in an adequate manner the special requirements of personnel, maintenance and safety of working.

Special experience is always neces-

(1) *Waggon und Lokomotivbau*, 1929, Nos. 8 to 11.

(2) *Zeitschrift des Vereines Deutscher Ingenieure*, 1930, No. 10.

sary for taking charge of a steam-driven locomotive, and if it is to be available for immediate service it must be kept constantly under steam. From these points of view the use of petrol or Diesel motors, has, under certain conditions, a number of advantages. The haulage units of this kind that were developed originally for use on construction works, were not adapted to the severer requirements of heavy duty service on standard gauge railways. The full advantages of the internal combustion motor locomotive could be brought to light only when the principles of steam locomotive construction were applied, as regards internal resistance and range of power.

The credit for taking the first step towards rationalising goods train operation is due to the Dutch Railways who in conjunction with Mr. Labrijn, one of its directors, first adopted internal combustion motor locomotives designed on these principles. This initiative also led the German Railways to pursue the development of vehicle construction, and eventually to introduce such units at so-called « wayside » stations, with a considerable reduction in the journey times of local freight trains. The money savings that can be attained by this means have been discussed by Herr Leibbrand (1). An important question that emerged related to the maximum output of such units on which point there had been hitherto somewhat vague data and opinions. The decision to adopt the new form of tractive unit depends not only on the reduction of the journey time, but more broadly on the all-round economy; the saving that is possible soon reaches a limit due to the rapid increase in the capital cost of an internal combustion motor locomotive as its power is increased.

Taking as a basis the figures given by Herr Leibbrand in the article cited, we obtain the following :

Considering the most unfavourable case, namely a motor locomotive working only two hours a day for 255 working days, and assuming the operating costs for such service for a year to be 30 % of the first cost, the permissible capital outlay on the assumption that the operating costs are to be the same as with steam, *i. e.* 12 Reichsmark per hour, would be approximately :

$$K = \frac{12 \times 255 \times 2}{0.3} = 20\,000 \text{ Rm. approx.}$$

Since the conditions just assumed are of frequent occurrence, the maximum power for a small motor locomotive of any particular type is well established; it varies, according to the type of motor — petrol or Diesel — from 40 to 60 H. P.

Outputs of this order are sufficient in most circumstances, since with modern conditions of working, the moving of wagons into or out of a particular station can be spread over and carried out to a large extent independently of the train schedule. Limitation of the permissible output by the capital cost fixes about 100 to 200 H. P. as the economic limit at the present time; there may, however, be exceptions to this in special circumstances. The important point is that small outputs can be transmitted through gearing without difficulty, whereas with larger outputs the difficulties of transmission increase very quickly. The actual construction of the vehicle is governed to a great extent by the conditions of service and the following description will indicate how these have been met.

In view of the experience gained by the Dutch Railways their type of vehicle was adopted in the first instance in order that its suitability for the conditions on the German System might be confirmed.

The type of motor to be used was governed primarily by considerations of

(1) *Reichsbahn*, 1930, No. 20 (*Author :* Herr *Leibbrand*, Reichsbahndirector).

low working cost and simplicity and this led to the adoption of a Diesel engine of the 2-cycle type. Of the first 15 units ordered, the majority were thus equipped, although it must be admitted that the development of this design of motor is still at an early stage, and its application to this kind of service is new. Experience with the first vehicles will show whether a correct choice has been made, but for purposes of comparison three petrol motor units were also ordered.

The locomotive built by the « Berliner Maschinenbau Aktien-Gesellschaft, late L. Schwartzkopff », the first contractors, was taken as a standard for the general design in the specification issued to the other manufacturers by the German State Railways. Individual firms were, nevertheless, permitted freedom as to the method of transmission, within the prescribed limit of cost, and could adopt chain, rod or spur-wheel drive. The first six small motor locomotives of the Schwartzkopff type have now been delivered; they comprise three petrol engines and three Diesel engines respectively.

These locomotives are a patented design of the firm in question and reproduce with insignificant variations the design which has been supplied to the Dutch Railways for several years; they embody development work and experience extending over four years.

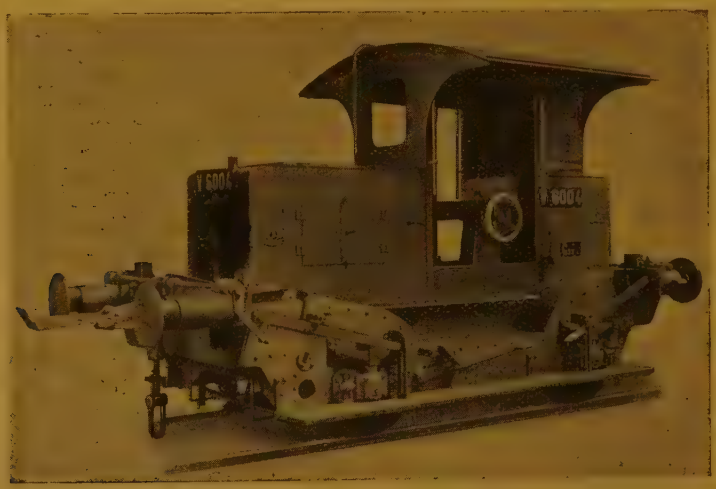


Fig. 1. — 40-H. P. small motor locomotive with petrol motor.

General design of motor locomotive (figs. 1 and 2).

The two types delivered to the German Railways differ only in the type of motor employed. Their principal dimensions are as follows :

	Diesel locomotive.	Petrol locomotive.
Gauge	1 435 mm. (4 ft. 8 1/2 in.).	1 435 mm. (4 ft. 8 1/2 in.).
Wheel diameter	850 mm. (2 ft. 9 1/2 in.).	850 mm. (2 ft. 9 1/2 in.).
Wheel base	2 810 mm. (9 ft. 2 5/8 in.).	2 505 mm. (8 ft. 2 5/8 in.).

	Diesel locomotive.	Petrol locomotive.
Length over buffers. . . .	6 315 mm. (20 ft. 8 5/8 in.).	5 805 mm. (19 ft. 9/16 in.).
Maximum width	2 700 mm. (8 ft. 10 5/16 in.).	2 700 mm. (8 ft. 10 5/16 in.).
Overall height.	3 250 mm. (10 ft. 8 in.).	3 250 mm. (10 ft. 8 in.).
Motor rating	40 H. P.	40 H. P.
Type of motor.	3-cyl. — 2-cycle.	4-cyl. — 4-cycle.
Tractive effort at speed V. .	1 500 kgr. (3 307 lb.).	1 500 kgr. (3 307 lb.).
Tractive effort at speed V' .	700 kgr. (1 543 lb.).	700 kgr. (1 543 lb.).
Maximum speed (per hour).	30 km. (18.6 miles).	30 km. (18.6 miles).
Weight in working order. .	12 100 kgr. (26 675 lb.).	12 100 kgr. (26 675 lb.).

As stated previously, these motor locomotives have been developed as a specialised form of traction unit for shunting service; consequently the details of the design have been governed to a very large extent by the desirability of meeting the special requirements of such work.

Even superficially they deviate widely from the usual lines of locomotive design.

The driving position is on either of two foot plates, one on each side of the loco, which are low enough to permit the driver to get on or off expeditiously; all the operating levers are duplicated on the two sides so that he can drive from whichever side gives him the best view of the track.

The frame has its centre portion between the axles lowered, and the cab is so arranged that the driver can move from one side to the other of the engine while running. The pedestal in the centre, that carries the control gear, serves also as a seat available on long runs.

The motor and gearing are mounted on a strong steel plate frame suitably stiffened by cross members and carried on leaf springs which transfer the weight to the axle bearings; roller type bearings are used to facilitate maintenance.

The ends of the frame are carried upwards at each end to accommodate the draft and buffing gear at about 1100 mm. (3 ft. 7 5/16 in.) above the rail level.

The serviceableness and economy of a shunting locomotive are determined by such factors as quick coupling and uncoupling, rapid braking, and simple and easy manipulation of the control gear. These essentials have been obtained by the special features that will now be described :

a) *Automatic draw-hook coupling* (figs. 3-5).

The coupling that is combined with the standard draw-hook consists of a simple toggle link and coupling stirrup which rides up the rear face of the draw hook on the wagon and falls into the jaw of the hook. For uncoupling, the whole automatic coupling is swung upwards on the coupling bolts and then lowered again; the coupling is then in the original position ready for coupling up again. This operation is performed by depressing a pedal from either of the driving positions.

In order that the ordinary coupling arrangement can be used when required, provision is made for hooking up the automatic coupling clear of the standdard draft gear.

b) *Control gear* (fig. 2).

The employment of a special design of drive, which will be referred to later,

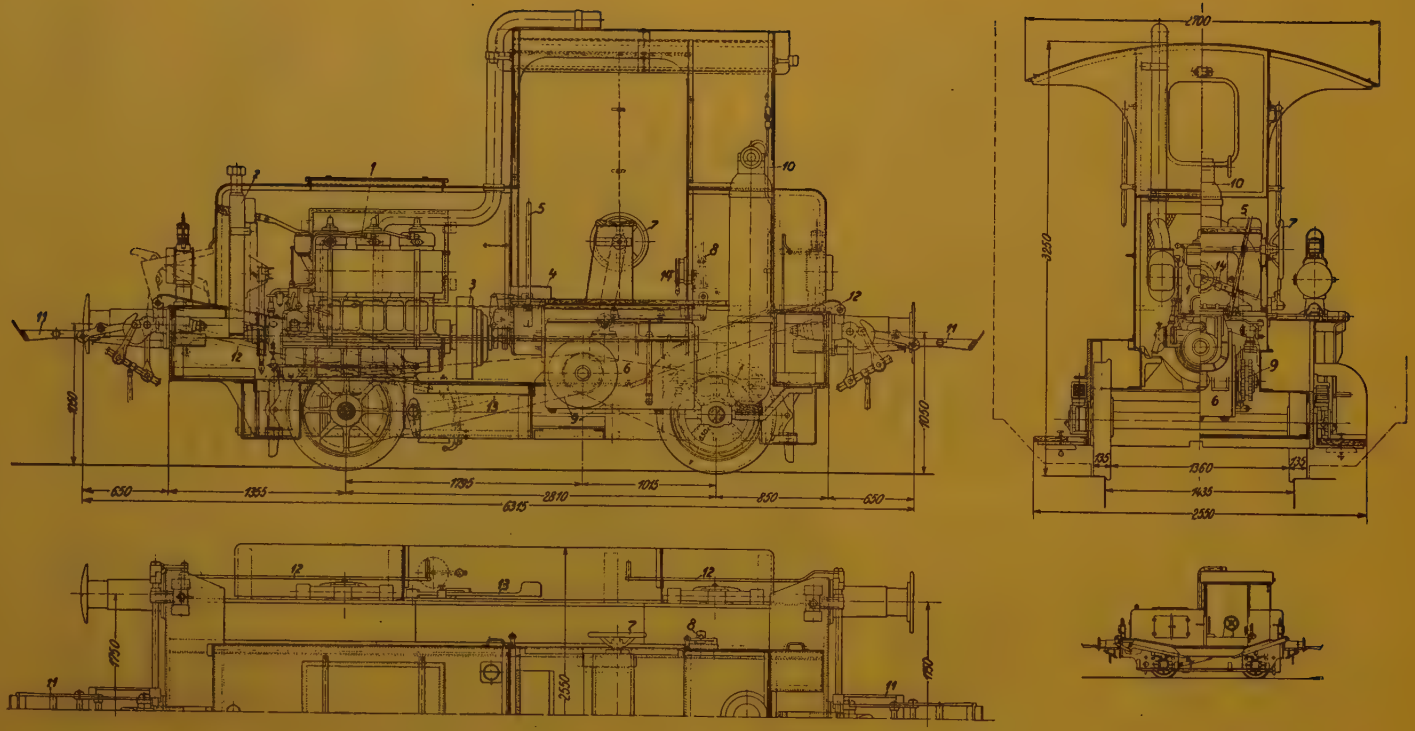


Fig. 2. — 40-H. P. small motor locomotive with Diesel motor.

KEY :

1. Motor.
2. Radiator.
3. Flywheel incorporating friction clutch.
4. High-speed drive.
5. Operating lever for high-speed drive.
6. Main drive.
7. Operating wheel for change-speed gear.
8. Reversing lever.
9. Chain drive.
10. Starting gear.
11. Automatic draw hook coupling.
12. Releasing lever for automatic coupling.
13. Foot brake.
14. Lever for speed regulation

has permitted the control to be simplified to such an extent that it is carried out solely by the operation of the large side control wheel. A quarter turn towards the left gives the first speed and a quarter turn to the right the second speed, without any shock. In the central position the motor is disconnected from the drive. No manipulation of the motor control is necessary when changing. Reversing is effected by moving a reversing lever into the desired direction of travel. When stopping for a short period during which it is not desired to switch off the motor, it can be throttled down by means of a control lever from either side.

c) *Brakes* (fig. 2).

A brake of the foot-operated type is provided so that the driver can effect quick and reliable retardation without detriment to the manipulation of the other controls. It is a fully-equalised four-wheel brake which utilises 60 % to 80 % of the adhesion weight for braking. The brake lever can be locked in the « on » position by a catch lever when the locomotive is left unattended.

The brake pedal is immediately below the large control wheel for the change speed operation, so that both these important controls can be worked without the driver having to move, or divert his attention from the shunting; they require no special skill for their operation and give him full control of the vehicle.

A multi-cylinder engine running at a moderate speed is the only type considered for use on a motor locomotive in view of its technical advantages for traction purposes.

For the loco-motors ordered by the German State Railways both Diesel and petrol engines have been used in order to obtain fuller information as to the suitability of each type for shunting service.

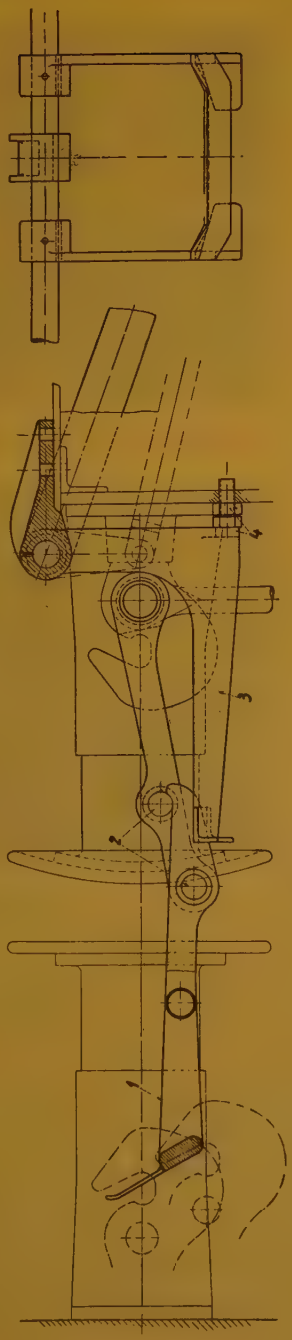


Fig. 3. — Automatic draw hook coupling.

KEY :

1. Draw-hook stirrup.
2. Toggle link.
3. Locking stirrup.
4. Adjusting device.

Fig. 4. — Automatic coupling in working position.

Fig. 5. — Automatic coupling raised to allow ordinary coupling to be used.

a) *Diesel motor.*

Main particulars.

Type	3-cylinder, 2-stroke, with crank-case scavenging.
Injection system	Separate chamber.
Cylinder diameter	150 mm. (6 inches).
Stroke	220 mm. (8 11/16 inches).
Continuous rating	40 H. P.
Speed	600 r. p. m.
Fuel consumption	200 gr. (0.44 lb.) of oil per H. P.-hour at full load.
Oil consumption for lubrication	8 gr. (0.0176 lb.) of oil per H. P.-hour at full load.
Maker	Humboldt-Deutzmotoren A.-G.

The engine works on the ordinary 2-cycle system and has crank-case scavenging.

Owing to the high compression, a special starting arrangement is fitted for operation by compressed air; the latter is produced by the engine, a part of the exhaust gases being passed through a valve into a 120-l. (26.4-Br. gallon) receiver, where they accumulate.

b) *Petrol motor.*

Main particulars.

Type	4-cylinder, 4-stroke.
Ignition	Bosch magneto.
Cylinder diameter	103 mm. (4 inches).
Stroke	166 mm. (6 9/16 inches).
Continuous rating	42 H. P.
Speed	1 000 r. p. m.
Fuel consumption	270 gr. (0.593 lb.) petrol per H. P.-hour at full load.
Oil consumption for lubrication	5 gr. (0.011 lb.) petrol per H. P.-hour at full load.
Maker	Motorenfabrik Heinrich Kämper.

As this engine can be started by hand, the fitting of an electric starting device has for the present been omitted. There is provision for starting by hand on both sides of the vehicle and it operates through bevel gear and a claw coupling which is disconnected automatically from the engine.

3. — Arrangement of gear drive (fig. 6).

For these locomotives of small power a gear drive has been adopted as being the simplest, cheapest and most reliable form of transmitting the power to the driving wheels. On the other hand, shunting service differs from road vehicle service in that large tractive effort is more important than high speed. Therefore it was not possible to adopt without alteration the type of design which has given such satisfactory results under entirely different conditions on the road. It was found necessary to work on entirely new lines in order to meet the new operating conditions in a satisfactory manner.

The guiding principles for the development of a gear drive suitable for locomotives are based on the necessity for transmitting comparatively large powers at low speeds, of reducing gear-changing to a minimum and of eliminating any difficulties even at the hands of unskilled personnel. It was recognised at the outset that all gears must be permanently engaged and that the gearing for each speed must be brought into action by a separate friction clutch; only by this means would it be possible to ensure the smooth operation which requires considerable skill with the ordinary design of gear changing.

As the friction clutch for each speed gear is preferably contained in the gear box, the most suitable form of clutch appeared to be the band type which had given good results for many years. It is compact and is not subject to much wear, its maintenance is simple and its operation absolutely reliable; these qualities are just those required for satisfactory operation under the rough conditions of locomotive service. It has been criticised on account of its rather fierce engagement, but this has been avoided in the small motor locomotives of the German State Railways by the

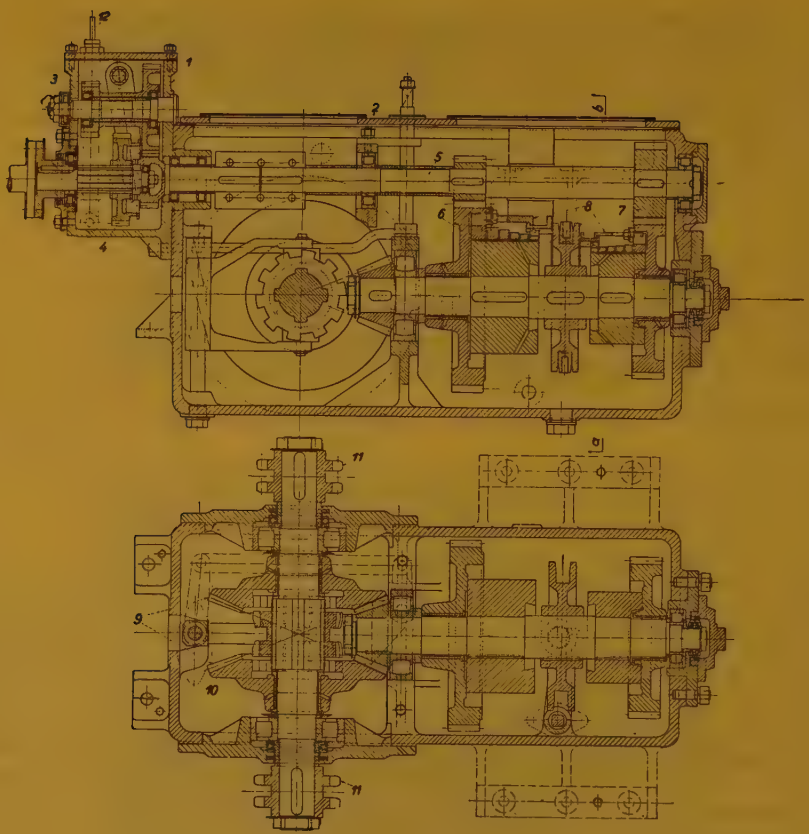


Fig. 6. — Gear box.

KEY :

1. High speed gear box.
2. Main gear box.
3. High-speed gearing.
4. Claw coupling for direct drive to main gear box.
5. Main driving shaft.
6. Gearing for lowest speed.
7. Gearing for second speed.
8. Band clutch.
9. Bevel reversing gear.
10. Claw coupling for reversing gear.
11. Chain sprocket.
12. Oil level gauge.

interpositon of a disc clutch in the main drive; as will be seen later, this clutch would have been fitted for other reasons.

The low horse-power of the motor, and the relatively large tractive force required in shunting service, naturally result in very low running speeds; as a rule a two-speed gear box is sufficient, which gives speeds of 5 and 10 km. (3 and 6 miles) per hour. This permits the adoption of a very accessible design of gearing, and most important of all, an extremely simple control arrangement which can be operated by unskilled labour. At the same time, higher

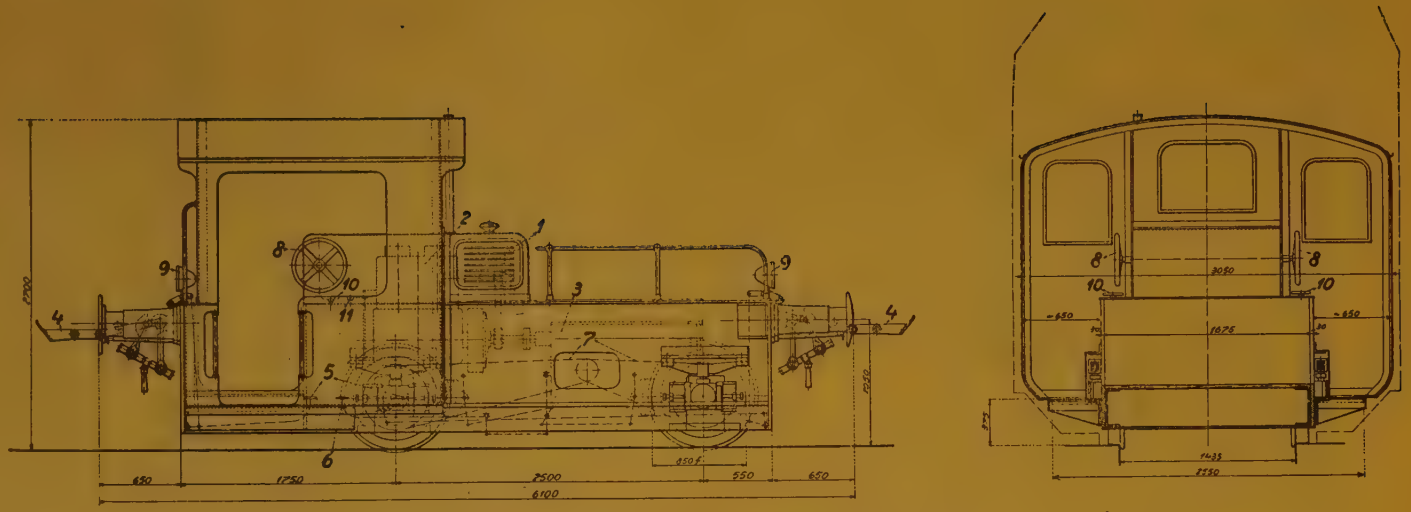


Fig. 7. — 50-H. P. small motor locomotive of the ate t type, embod ing a 50-H. P. petrol motor with electric starting equipment.

KEY :

1. Radiator and fan.
2. Motor.
3. Main drive with self-contained high-speed gear.
4. Automatic coupling.
5. Foot release for automatic coupling.
6. Foot brake.
7. Chain drive.
8. Operating wheel for changing gear.
9. Electric lighting.
10. Speed regulator for motor.
11. Reversing lever

speeds are required when the locomotive is running light, in order to enable it to run into and out of sidings quickly, and also from one station to another. This requirement has been met without sacrificing the great advantages of the simple two-speed gear box.

For this purpose a high-speed gear box is interposed between the motor and the main drive of the two-speed gear box, and this gives a multiplication of the normal working speed. The arrangement of this gear is clear from figure 6.

It is clear, therefore, that the locomotive has two speed ranges either of which the driver can bring into use by means of a special control lever. The change-over is made with the locomotive at rest and with the motor disengaged; a friction clutch is fitted in the motor flywheel for this purpose, and it serves also as a slipping coupling to protect the motor effectually from excessive loads or shocks, while also counteracting any harshness in the action of the band clutches.

Reversal of the direction of travel of the locomotive is brought about by a simple form of bevel reversing gear.

4. — Chain drive (fig. 2).

There has, of course, been a great deal of discussion as to the best method of transmitting the power from the main drive that is fixed rigidly to the frame, to the sprung axles of the vehicle. From the point of view of the railway engineer the chain-drive is undoubtedly preferable to a connecting-rod drive; it requires little maintenance and transmits the torque quite uniformly. Moreover the use of a chain-drive gives the maximum freedom for the arrangement of the motor and gearing and renders possible the adoption of a standard design for any gauge.

The method of transmission was not specified by the German State Railways, but Messrs. Schwartzkopff decided to use chain transmission on their contract as they had previously obtained good results with it.

When the first locomotives had been put into service it was recognised that certain improvements were desirable from a practical operating point of view. There are many occasions when it is necessary for the driver to change his position from one side to the other, and the surmounting of the raised portion in the centre is both tiring, and in bad weather, likely to be dangerous. An endeavour was made, therefore, while retaining the other special features, to find the best design that would bring the passage way as low as possible. If the general principles of locomotive designs are adhered to, this reduction in height of the platform can only be achieved by moving the driving position to the end of the vehicle where the plate frame can be cut away accordingly. By permitting a step of normal height it is possible to design the frame at this point so as to meet all reasonable requirements. A complete cab has also been fitted as it was considered desirable to reduce the risk of the driver slipping off the foot-plate and to protect him from the weather. The entire arrangement, while retaining the standard drive, permits the lowering of the motor and gearing so as to give the driver a clear view of the automatic couplings from the cab, in which he can drive from either side, and at the same time he has an unimpeded view at each side of the wagons that are being shunted (fig. 7).

The introduction of these small motor locomotives marks another important advance in the direction of rationalising railway operation.

[621. 39 (73) & 669 (.73)]

Industrial electric heating for railway shops,

by WIRT S. SCOTT (1),

Figs. 1 to 10, pp. 872 to 884.

(*Railway Mechanical Engineer.*)

Although the use of electricity for heat treating has extended to many industries, comparatively little was known until recently of the steam-railway industry's attitude towards the use of electric heat for this purpose. For this reason it was decided to make a study of the economic value of electrical-heating equipment in the Norfolk & Western shops at Roanoke, Va., these shops being selected for such an analysis because electricity is widely used there for heating purposes.

Equipment of many different manufacturers is represented at the Roanoke shops. Irrespective of the kind, type or make of the equipment used, an attempt was made to determine in a concrete manner the advantage of such equipment in comparison to past practice. All of the equipment was found to be giving a good account of itself and the repairs to it have been negligible. The following table contains a list of the equipment which was studied to obtain comparative cost data.

The Roanoke shops are not completely electrified, the Norfolk & Western's problem being similar to that of other companies, i. e., financing the expenditure.

Electrical heating equipment used in the Norfolk & Western shops at Roanoke, Va.

Babbitting department	102 kw.
1—50-kw. melting pot for melting down old bearings.	
1—30-kw. tinning pot for brasses.	
1—22-kw. babbit melting pot.	
Electrical department	30 kw.
1—30-kw. armature baking oven.	
Tool department	51 kw.
1—8-kw. preheating and tempering furnace.	
1—13-kw. hardening furnace, carbon steel.	
1—30-kw. hardening furnace, high-speed steel.	
Forge department	240 kw.
2—120-kw. carburizing furnaces.	
Core-making department	555 kw.
3—185-kw. core-baking ovens	
Foundry	540 kw.
1—540-kw. annealing furnace.	
Additional equipment.	
1—Steel melting furnace . . .	1 000 kw.
1—Rivet heater	30 kw.
Miscellaneous glue pots	5 kw.
Crane cab heaters	10 kw.
Total connected load	2 563 kw.

From the study of the equipment installed, however, it has been determined that electric heating is economical, accurate, dependable, and that the following advantages are obtained :

1. Uniformity of heating.
2. Ease of control.
3. Continuity of operation.
4. Quality of product.
5. Speed of production.
6. Maintenance.

(1) The author is special representative of the Westinghouse Electric & Manufacturing Company.

Fig. 1. — Heat treating department for small tools.

Fig. 2. — One of the 120-kw. carburizing furnaces.

Approximately 1 500 lb. of carburized parts are obtained per charge with an average production of 2 lb. per kw.-h. a cost of $ 0.004 per lb

7. Confidence in the heating process.
8. Removal of uncertainty in the manufacturing process.
9. A dependable and uniform-quality product.
10. Greatly improved working conditions.

Tool heat-treating department.

In this department are heat-treated the high-speed and carbon-steel tools such as are used in many large machine shops where a wide variety of work is being done, particularly on heavy parts. The furnace equipment includes a preheating furnace for high-speed steel; a hardening furnace for carbon steel which is also used for preheating high-speed steel at temperatures between 1 400 and 1 650° F., and for tempering alloy steel, and a furnace for hardening high-speed steel at 2 250° F. The preheating furnace is also used as a tempering furnace. The size, capacity and range of these furnaces are as follows :

Preheating furnace.

Hearth area : 12 in. by 22 in. by 8 in. high.
Electrical capacity : 8 kw., 1 phase, 110 volts.
Range of operation : 400° F. to 1 850° F.

Hardening carbon steel.

Hearth area : 12 in. by 28 in. by 8 in. high.
Electrical capacity: 13 kw., 1 phase, 220 volts.
Range of operation : 1 000° F. to 1 850° F.

Hardening high-speed steel.

Hearth area : 10 in. by 18 in. by 6 in. high.
Electrical capacity : 30 kw., 220 volts.
Range of operation : 2 000° F. to 2 500° F.

The operation of heat treating high-speed steel blanks 1/4 inch by 1 inch by 6 inches consists of placing them in the 8-kw. furnace at a temperature of 1 000° F., and soaking them for one hour; removing and placing the blanks in the 13-kw. furnace at a temperature of 1 600° F., and soaking them for one-half hour; removing and placing them in the 30 kw. high-speed-steel hardening furnace at a temperature of 2 250° F., for 5 minutes. The furnaces in this manner are operated at the maximum production capacity, the highest efficiency, and the greatest refinement of the steel and the elimination of heating strains are effected.

Chrome-steel die blocks are hardened at 1 600° F., quenched in oil, tempered at 950° F., and cooled in air. Shear blades are hardened at 1 450° F., quenched in water, and tempered at 420° F. Insert blades for reamers are hardened at 2 250° F., quenched in oil, and tempered at 1 050° F., and cooled in air.

The heat-treater in charge of these furnaces reports that since the adoption of electric heat, all guesswork has been eliminated. Experience has taught him that the heating characteristics of the electric furnaces are such that they become definite, with the result that, for each piece heat-treated, a definite time can be allowed for complete saturation. This procedure, supplemented by uniformity of chamber temperature and automatic temperature control, has completely revolutionized methods of operation and results. It is no longer necessary to watch the work, and to attempt to judge by its color if and when properly heated.

The exactness of heat-treatment has been reflected in the increased life of the tools, a natural consequence. Since all the tools pass through the tool-grinding department, an investigation was undertaken to determine the tangible results of electric heat-treatment. A record was secured in connection with high-speed steel tools, showing that the tool cost has decreased 25%, and that the life increased one-third. There are 11 men in the grinding department as follows : three men on new work exclusively, two men grinding milling cutters, and five men who spend 75 % of their time on old tools and the balance on new tools. The present hourly cost for refi-

nishing tools is $4.21, based on two men at 80 cents per hour, or $ 1.60, and 75 % of five men's time, or $2.61. One-third of $4.21, or $1.40 is thus saved per hour in labor, or $291.20 per month.

The records also show that at present an average of 1 400 lb. of tool steel are worked up per month, at a cost of 60 cents a pound, or a total purchase price of $840. With the tools lasting one-third longer, since using electric heat, the saving based upon present operating conditions is $280 per month. The total saving is therefore $571.20 per month.

A rough estimate was made as to the monthly power consumption of the three electric furnaces, based upon observed operating conditions over a period of four days. Such computation showed an estimated monthly consumption of 6 250 kw.-hr. which would cost, at an 8-mill rate, exactly $50 a month.

The investigation was extended to the machine shop for the purpose of determining whether or not the machinists have observed any difference in the life of tools. The older and more experienced men reported increased life anywhere from 30 % to 50 %. In turning steel axles, for instance, the workmen report that they are now getting a 4-foot cut compared with a 3-foot cut which was considered a very high average in the past.

Carburizing furnaces.

In the maintenance of locomotives, there are a large number of parts to be carburized, such as wrist pins and bushings, equalizer bushings, split side-rod bushings, brake pins, spring-rigging pins, knuckle pins, die blocks and die-block pins. All of these parts are placed in nickel-chromium carburizing boxes, and packed with crushed bone.

The parts are made of low-carbon steel so as to give maximum toughness, and then given a high-carbon case, 3/64-inch thick for maximum surface wear. The heat treating is done at a temperature of 1 650° F. Two electric furnaces are available, each having a rating of 120 kw. capacity, with an effective hearth area 42 inches wide, 56 inches long and 20 inches high.

These furnaces are of the roller-hearth type, with the rollers extending about 6 feet outside the furnace, so the boxes may be packed in position and rolled into the furnace. This operation requires the services of two men. Two different size boxes are used, one 16 inches by 22 inches by 18 inches high and another 16 inches by 50 inches by 18 inches high. Two large boxes, or four small boxes, or one large and two small boxes constitutes one charge.

The furnace is charged every afternoon at 5 p. m. Usually from 12 to 16 hours are required per heat, depending upon the weight of charge. An average charge will weigh from 1 400 to 1 500 lb. net of material to be carburized, 1 100 to 1 200 lb. of carburizing boxes, and approximately 500 lb. of crushed bone.

A test was made on one of the furnaces to determine the heating characteristics and power consumption. The furnace was charged with 980 pieces of work totaling 1 436 lb.; carburizing boxes, weighing 1 148 lb., and crushed bone, weighing 505 lb., a total gross weight of 3 089 lb. Other data and results of this test are as follows :

Furnace temperature at start.	860° F.
Operating temperature	1 650° F.
Time in	5 p. m.
Time out	6.10 a. m.
Time for furnace thermocouples to reach 1 650° F.	2 h. 45 m.
Time furnace is held at 1 650° F.	10 h. 25 m.
Total time	13 h. 10 m.
Kw.-h. consumed in reaching 1 650° F.	328
Kw.-h. consumed after reaching 1 650° F.	400
Total kw.-h. consumed	728

Fig. 3. — The 540-kw. car type furnace for normalizing steel castings.
It operates from four to five nights a week with a consumption of from 400 to 500 kw.-h. per ton castings.

Fig. 4. — A 300-H.P. stator, impregnated with an insulating varnish, about to be placed in the armature-baking oven.

Gross pounds of material per kw.-h.	4.25
Net pounds of work carburized per kw.-h.	1.97
Cost of power per charge, at 0.8 cent par kw.-h.	$5.828
Net cost of power per pound of material carburized	$0.00406

Tests made on carburized parts show a remarkable uniformity of case regardless of the location of the part in the furnace or in the box. With fuel-fired furnaces, absolute dependence could never be placed on the product, since in some parts of the furnace the case of the product would be less than one-half of that in other parts, and the heat treatment was largely a matter of guesswork and compromise of results. With the electric furnace, the operation has become one of timing, so that with a certain charge, the foreman knows how long a period will be required for obtaining a definite penetration, with the assurance that the penetration will be the same throughout the entire charge.

Because of the much greater exactness of heat treatment resulting from the use of the electric furnace, it is estimated that the useful life of many of the major pieces of all the carburized parts has been more than doubled. This has resulted in less replacements of such worn parts, a very substantial saving.

Cold-rolled steel bushings average 29.32 cents per pound finished, and ready for application, including material, labor, shop expense and stores expense. The labor cost for installation averages 20 cents.

Brake and spring-rigging pins average 8.77 cents per pound, finished and placed in stock. No additional charge can be added for labor of replacement, since these pins must be removed for periodic inspection, and are then replaced if they show too much wear.

On the basis of 20 charges a month, and 1 450 lb. of material per charge, 29 000 lb. will be heat-treated per month, which will be made up of approximately 9 000 lb. of bushings, 18 000 lb. of pins, and 2 000 lb. of miscellaneous products. The values of these parts are as follows :

9 000 lb. bushings at 29.32 cents per lb. for manufacturing	$2 628.80
9 000 lb. bushings at 20 cents per lb. for installation.	1 800.00
18 000 lb. pins at 8.77 cents per lb. for manufacturing.	1 578.60
Total value per month.	$6 007.40

Twenty-five per cent of $6 007.40 or roughly $1 500 per month represents the minimum net savings since using electric heat, for pins and bushings. The cost of heat treating these parts, a total of 27 000 lb. is $109.02. With a saving by extended life on the remaining 2 000 lb. of miscellaneous parts in proportion to that of pins and bushings, the total monthly savings and expense will be $1 560 and $117.74, respectively.

The savings in the above case is 13 times the cost of electric power. That the life of the carburized parts has been increased is also shown by the fact that one electric furnace is now handling the repair parts for which two were originally required.

Annealing steel castings.

A coke-fired furnace was first installed at the Roanoke shops for the heat-treatment of steel castings, then this furnace was replaced with one heated with oil. Whenever the doors of the coke furnace were opened to add more fuel, the temperature within the furnace chamber would drop from 75° to 100°. With the oil-fired furnace, a series of tests disclosed the fact that the temperature at all parts within the furnace were nowhere near the same, with the result that a great non-uniformity of physical properties was disclosed even within the same castings. A casting with

many heavy sections may have one such section located either in a cold area or in a part which is slow to come up to heat, so that the surrounding temperature may be either too low, or not of sufficient duration to permit thorough penetration.

Test samples only indicate the conditions at the point of the sample. One foot away, an entirely different result may be secured. Obviously there was no system of inspection and testing that would insure a 100 % properly heat-treated product in a furnace heated by a high-temperature flame and convection currents. No two burners will produce exactly the same amount of heat, the heating is done more or less in spots, and is not capable of being uniformly distributed and controlled in a manner which will insure every part of every casting being properly heat-treated.

A decision was made to replace the oil-fired furnace with an electric furnace, solely on the basis of producing the kind of casting having the physical properties desired. The electric annealing furnace was installed in 1927, at a total cost of $16 500. It has an electrical capacity of 540 kw., a maximum charge capacity of 20 tons, an average capacity of 12 tons, and a loading space on the car 7 feet wide, 14 feet long and 5 feet high.

This furnace was charged with a test load of 13 tons, consisting of miscellaneous car castings and the following :

1—Engine saddle	3 000 lb.
1—Front foot plate	1 800 lb.
2—Driving boxes	600 lb.
1—Grate rest	1 565 lb.
1—Driving wheel	2 500 lb.
1—Back cylinder head	600 lb.
2—Driving boxes, oversize	950 lb.
3—Front cylinder heads	500 lb.
2—Chafing blocks	200 lb.
4—Truck boxes	150 lb.
4—Valve-head extensions	325 lb.

All of the above castings were given a normalizing heat-treatment, which consists in heating the castings at a temperature of 1 650° F., until thoroughly saturated, and then pulling the car out into the air for an air quench. The electric furnace heats uniformly top and bottom, end to end, and by allowing one hour soaking period per inch of the heaviest cross section of the casting, from the time the temperature of 1 650° is reached, it has been found that the entire charge will be thoroughly heated.

The car-type furnace is operated from four to five nights each week. With a charge as above described, the furnace will require 9 hours to reach 1 650° F., and the temperature held at 1 650° F., for 6 hours, making a 15-hour heating cycle.

Some parts, such as engine frames, are given a double heat-treatment for the purpose of giving such members greater ductility. This consists in heating the charge at 1 650° F., for 10 hours, remove and allow to cool until black, reheat to 1 250° F. for 10 hours and remove into the air.

In addition to securing a properly annealed casting, the outstanding result was the decreased cost of machining the castings. Workmen in the machine shop praised the electric annealing furnace very highly. It is very seldom that a hard spot is now encountered, the breakage of tools is much less, more cuts are obtainable, and the steel has a much better grain or texture.

As near as could be determined, the machining costs have been decreased 10 % since electrically annealing the castings. There are a total of 250 machinists, 50 % of whom work on steel castings. At an 80-cent hourly rate, the hourly cost for machining these castings would be $100 or a monthly cost of $20 800. Since it has been estimated that the savings over previous cost is 10 % and the previous cost, based on present

production, was $23 200, the net monthly savings in labor for machining would be about $2 400.

Power consumption.

For a 13-ton charge, with the furnace started cold, or approximately so (the current having been cut off for 32 hours), the power consumption was as follows :

Power required to reach 1 650° F.	4 860 kw.-h.
Power required after reaching 1 650° F.	1 620 kw.-h.
Total power required	6 480 kw.-h.
Consumption per ton	500 kw.-h.

A consumption of 500 kw.-h. per ton is much higher than the average, since this figure was based on a test in which the furnace was not used the preceding night. In addition, the furnace door was held open for a considerable portion of the time in arranging for photographs of the charge prior to heat treatment. The furnace ordinarily would have come up to operating temperature in 7 hours with a total consumption of 5 400 kw.-h. or 415 kw.-h. per ton of steel castings.

A second test charge was heat-treated, the charge weighing 20 tons and consisting of very heavy castings, such as locomotive driving wheels and frames. The operating data of this charge is as follows :

Total weight of charge	40 210 lb.
Time required to heat charge from atmospheric temperature to 1 650° F.	11 h. 15 m.
Time required for soaking charge at 1 650° F.	9 hours.
Total time of heating cycle	20 h. 15 m.
Power for heating up charge (11 1/4 hour at 512 kw. per hour)	5 760 kw.-h.
Total power used	7 760 kw.-h.
Kw.-h. for soaking charge.	2 000
Total lb. annealed per kw.-h.	3.18
Kw.-h. per ton	392

Assuming a conservative estimate of 450 kw.-h. per ton on a monthly basis of a production of 170 tons of steel castings annealed, the operating cost would be as follows :

Basic power cost per kw.-h.	$0.008
Tons per month.	170
Kw.-h. per ton	450
Power cost per ton, average	$3.60
Power cost per month	$612.00

Using fuel-fired furnaces, it was necessary to have a man on duty continuously to look after the furnace. With electric heat, it has been possible to dispense with such help, since the only attention required is on the part of the night watchman, who punches a clock alongside the control panel for the electric furnace, and all he has to do is to note if the indicating lamps are burning. This saving in labor is $118.50 per month.

Summary.

Monthly saving in machining of steel castings.	$2 400.00
Monthly saving in labor of attending furnace	118.50
Total monthly saving	$2 518.50
Monthly cost of electric power	$ 612.00

There is an additional saving not mentioned in the foregoing—that of breakage of tools on account of hitting of hard spots in the castings. There was no way of arriving at this saving except in a very vague manner. A great deal less trouble was being experienced, and as a matter of fact, it has just about been eliminated. As an indication of what this tool breakage, and additional grinding and wearing out of tools may amount to, the saving in tools, in one case analyzed, amounted to ten times the labor saving. This may have been an exceptional case, but it would seem that one could conservatively estimate the saving in tools would at least equal the saving in labor, for the entire shop.

Core baking ovens.

The use of electricity on a large scale in the Norfolk & Western shops at Roanoke, Va., for heating core-baking ovens was of unusual interest since this form of heat for core baking has not received general acceptance to the same extent that it has in other applications.

There are three large electrically-heated core-baking ovens in operation, each oven being 8 1/2 feet wide, 17 1/2 feet deep and 11 1/2 feet high. The electrical capacity of the ovens is 185 kw., 3 phase, 60 cycle, 220 volts. They are truck operated, each oven holding 2 trucks, 6 feet wide by 8 feet long, weighing 9 000 lb.

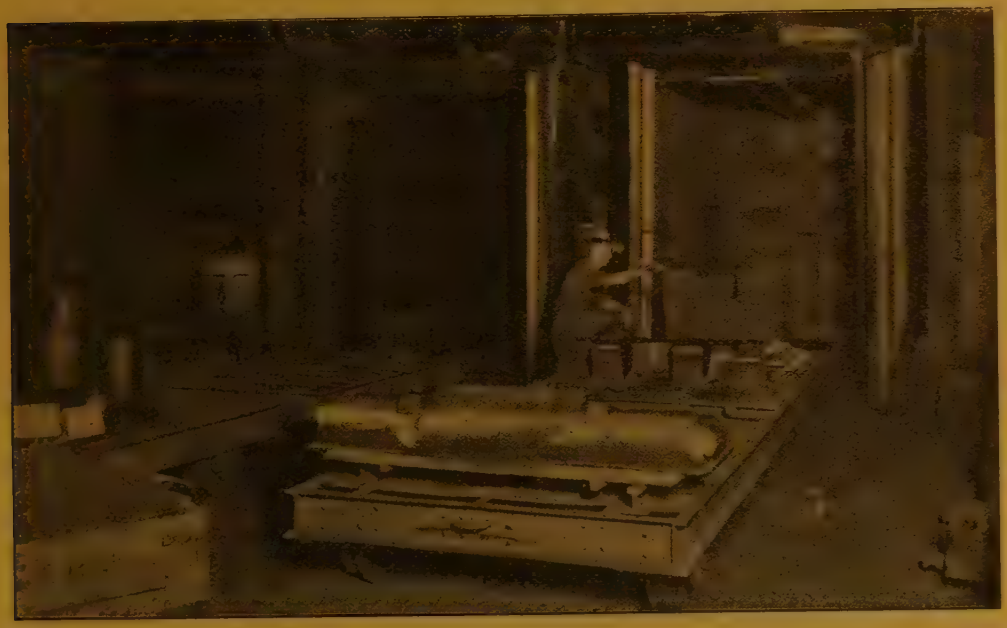


Fig. 5. — Core-baking ovens Nos. 1 and 2, each having an electrical capacity of 185 kw.

The installation of electrically heated core-baking ovens has resulted in a reduction of steel castings valued at many times the cost of the electric current.

Cores made at these shops are usually quite large. The loss of such cores or the castings in which they are used represents an appreciable sum of money. Hence, an investigation was made to determine if any evidence was available as to actual savings made since the installation of electrically-heated equipment.

An interview with the foreman and assistant foreman, brought out the facts that with the use of coke-fired core-baking ovens, they had to depend on labor to fire the furnaces and attempt some sort of temperature control. The oven was often either too hot or not hot enough, with the result that most cores were underbaked, while a considerable number were overbaked. Occasionally the entire day's work of a core maker

would be lost when burned cores would fall to pieces. Castings were repeatedly lost on account of blow holes caused by green or partly baked cores. In many instances, these small holes, caused by the escape of excess vapor, did not show up until the casting was being machined, and sometimes the major part of the machining had been done before the defect could be discovered.

Since using electric heat an improvement has been noted in the castings. The difficulty of blow holes resulting from underbaked cores has been completely eliminated. An average charge of cores per oven will weigh 9 000 lb., and the power consumption is 800 kw.-h. per bake. At a rate of 8 mills, the power cost is $6.40 per oven per bake, or $19.20 for the three ovens. The average value of the cores for the three ovens is $150 including labor and material, and for the steel castings annealed and sand blasted $2 000. The saving in loss of cores is placed at 3 %, or $4.50 per day, and the saving in the loss in steel castings at one and 1 1/2 %, or $30 a day.

Using fuel-fired ovens, the labor of 75 % of one man's time was required for firing and watching the ovens. This amounts to 6 hours at 57 cents per hour, or $3.42 per day.

A summary of the total annual savings for the three electric core-baking ovens shows the following :

Savings due to spoiled cores	$1 350
Savings in steel castings	9 000
Labor for attending ovens	1 026
Total gross savings	$11 376
Power cost	5 760
Net savings per year.	5 636

A summary of the opinion expressed relative to the electric core-baking ovens indicated that the objections raised in connection with the coke-fired ovens had been minimized and in some cases entirely eliminated.

Armature baking oven.

In the electrical repair department there is installed an oven for baking varnish on electrical coils, such as armatures, field coils, stators, and locomotive headlight generators. These parts, when brought in for repairs, are given a final treatment of an impregnating varnish and then baked in an electric oven from 24 to 72 hours at a temperature of 250° F.

The oven is a standard product designed and sold for such purposes. The inside dimensions are 4 ft. 2 in. wide, 9 ft. 8 in. long, 6 ft. 2 in. high in the clear, exclusive of the space required by the heaters mounted along the sides. An exhauster set is used for forced ventilation and for recirculating the air. The electrical capacity is 30 kw.

The foreman of the electrical department stated that from his records, the useful lives of the coils impregnated and baked in the electric oven had been extended to double the life prior to the adoption of the method. When baking the coils in a fuel-fired oven, it is practically impossible to maintain sufficiently close temperature regulation to prevent underbaking or overbaking coils, which treatment is not better than no baking at all. This is advanced as the reason why electrically-baked coils have doubled the life of those used before the installation of the electrical equipment. Small coils are dipped in the varnish, allowed to drain, and hung up in the oven for baking. Large coils are sprayed with a spray gun and run into the oven on a truck. All coils are thoroughly baked out before being impregnated. The oven has been in operation, day and night, seven days a week, for five years and not one cent has been spent for repairs.

In the winding department there are four armature winders and four laborers employed at a total labor cost of $1 456 per month. Since the life of coils has

been increased 100 % since using the baking oven, the amount of labor that would be required in the winding department would have amounted to $2 912 a month, or a direct saving of $1 456 a month or $17 472 per year.

Babbitting bearings.

The babbitting department process consists of melting down the babbitt from the old journal bearings, machining and tinning the brasses, babbitting and milling the bearings. The worn out journal bearings coming into the department are delivered in a truck alongside an electrically-heated rectangular melting pot, 20 inches wide, 54 inches long, 18 inches deep, which is heated with five 10-kw. immersion heaters. The temperature of the bath is regulated automatically at 700° F. The brasses are placed directly in the bath, and when the level of the bath rises near to the top of the vessel, the babbitt is ladled out into molds, producing pigs weighing 80 lb. each.

From 400 to 500 worn out bearings are melted down each 8-hour day. After each brass is removed from the bath, it is thoroughly brushed with an air-driven revolving brush, and then inspected for cracks, flaws, or any defects which would make it unsuited for further use. This results in 50 % of the brasses being discarded and scrapped. Those passing inspection are placed in a truck, and conveyed to a double milling machine, operated by two men, who mill out the brasses so as to obtain a bright surface for the tinning of the bearing.

The tin pot is also rectangular, 20 inches wide, 30 inches long, and 18 inches deep, and is heated with four 7 1/2-kw. immersion units, having automatic control. The brasses are swabbed with muriatic acid, placed in the tin bath, and kept there in readiness for receiving the babbitt.

The brasses are removed from the tinning pot in pairs, placed on a mandrel, and held in place by means of push rods operated by compressed air cylinders. The babbitt is then ladled into the brasses. The babbitt pot is of the circular type, 21 inches in diameter and 19 inches deep and has 22-kw. capacity, with automatic temperature control. The babbitt used is a lead base, having an approximate composition of 4 % tin, 8 % antimony and 88 % lead. Approximately 1 200 lb. of old babbitt and 1 200 lb. of new babbitt is used every eight hours. The old babbitt is analyzed and a make-up added to keep up the analysis.

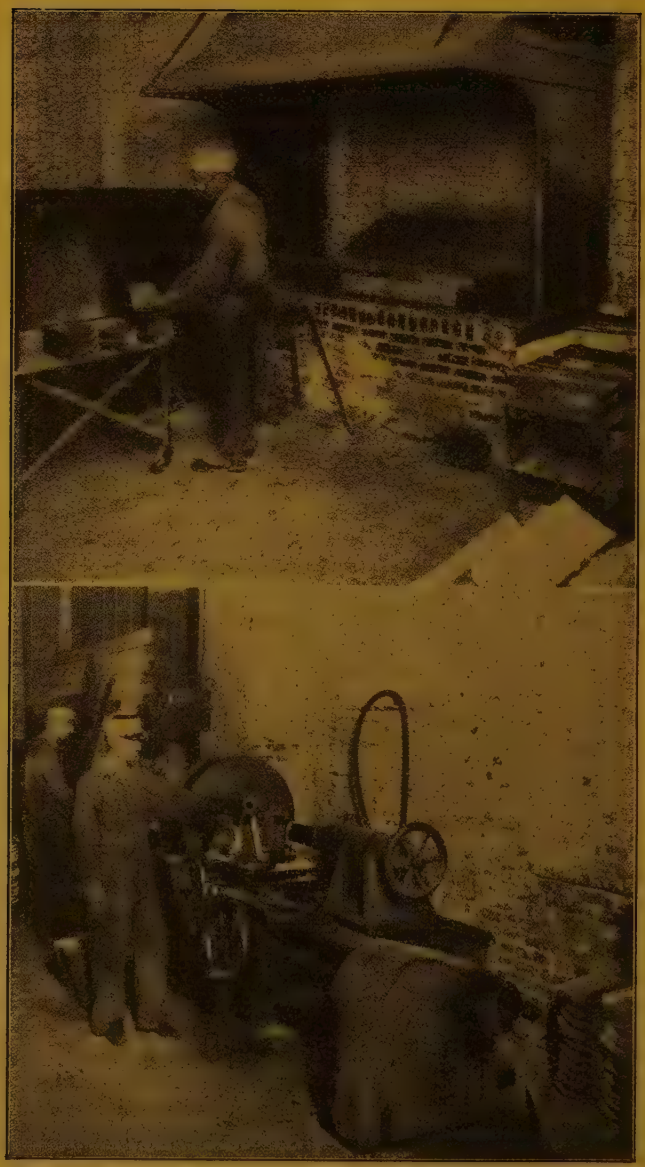
After the bearings are poured they are smoothed off and placed in a finishing milling machine, where they are bored out to exact size.

An analysis of the advantages of electric heat in this department disclosed that the life of a bearing is affected by the temperature to which the babbitt is heated. Ã variation in temperature of 200° F. from normal will result in a bearing life of only one-fifth of the life that should be obtained under proper temperature conditions. Overheating the babbitt, followed by pouring at the proper temperature is as injurious as pouring at the overheated temperature.

With the coke fuel previously used, a wide variation in temperature resulted. Since using electric heat, the temperature is automatically maintained at a predetermined point, and it is conservatively estimated that the bearing life has been more than doubled.

There are nine men, including laborers, in the babbitting department who are engaged in melting down old journal bearings and cleaning brasses, machining brasses, tinning bearings and babbitting, trimming and milling bearings. The total labor cost is $4.75 per hour.

With a production of 5 000 bearings a month, at a labor cost of $988, the average labor cost per bearing is 19.25 cents. An average of 1 200 lb. of new babbitt



Figs. 6 and 7. — Top : Electrically heated melting pot where the babbitt is melted out of the old bearings.

The brasses are cleaned with a revolving brush, inspected, and those passing the inspection are sent to the boring machine.

Bottom : The double lathe used for boring the brasses after inspection.

metal per day is used, or 27 200 lb. a month, at 25 cents per pound, making a metal cost of $6 800, or $1.36 per bearing. The total labor and material cost is therefore approximately $1.55 per bearing.

Using fuel-fired furnaces for melting the babbitt it is estimated that the percentage of worn out bearings for various causes would be distributed as follows : general wear and tear, 50 %; improper lubrication, 25 % ; poor babbitting, 25 %.

An analysis of the above would indicate that 25 % of the bearings may be defective on account of not being poured at the proper temperature, and that 75 % may fail because of wear and tear or improper lubrication before they have a chance to wear out. The savings that may be said to be effected directly by the babbitting will be 12.5 % of the total failures, or 625 bearings on a monthly production basis of 5 000 bearings. With the cost of labor and material set at $1.55 per bearing, the monthly savings would be $968.75.

Each of the 625 bearings worn out prematurely must be replaced in the car, at an average labor cost of 77 cents per bearing, or a total cost of $481.25 per month, for labor of replacing bearings.

No record was available as to the former cost of fuel, or the present power consumption. On the basis of similar installations, a conservative estimate can be made of the electric consumption as follows :

The connected load is 102 kw. The average hourly consumption will be 70 % of this, or 71 kw. per hour for 208 hours per month, or 15 000 kw.-h. During the heating-up period each morning, the power is on continuously for 90 minutes, which will add 4 000 kw.-h. per month, making a total of 19 000 kw.-h. consumed. At a rate of 8 mills, the cost will be $152 per month.

From the foregoing, it will be noted that the net monthly saving is $1 450, the total of the babbitting-operation savings of $968.75 and the savings effected by eliminating premature installations of bearings, which is $481.25. Since the monthly cost of electric power is $152 the production of better babbitt and longer life of bearing is therefore worth 9.6 times the cost of the electric power.

Another interesting phase of this situation is that the American Railway Association (A.R.A.) interchange cost of rebabbitting and replacing 6-inch by 11-inch journal bearings is $2.50, which is the difference between $7.50, the cost of a new brass, and $ 4.90, the allowance on the old one.

With an extended life of 100 % on 25 % of the bearings, the possible savings on the basis of a billing of $2.50 per bearing replaced by foreign railroads above will represent a considerable sum each year.

The arc-type steel-melting furnace, used in the foundry at the Roanoke shops was originally rated at 3 1/2 tons capacity, but is now being operated at a capacity of 4 1/2 tons per heat. It was installed to facilitate the securing of castings for repair parts.

Three heats are secured each night. The molders finish their work at 4 p. m. and by 5 or 5.30 p. m. the first heat is ready for pouring. The first heat requires approximately 3 1/2 hours from the time the current is first turned on until it is ready for pouring. Successive heats require from 2 1/2 to 3 hours.

The current consumption averages approximately 740 kw.-h. per ton, a commendable performance considering that the furnace is in operation only from 12 to 13 hours per day. The furnace is operated entirely on scrap materials, made up largely of couplers, angle bars, borings and turnings.

General summary.

In the analysis given in the foregoing, nothing has been said about the former cost of fuel, or the relative maintenance costs of fuel and electric furnaces. The

Fig. 8. — The rectangular tin bath electrically heated, into which the brasses are placed.

The brasses are kept in the bath until ready for receiving the babbitt.

Fig. 9. — Two brasses are placed on a mandrel and held in place by air-operated push rods.

The electrically heated babbitt pot is shown in the foreground.

Fig. 10. — After the bearing has been poured and the edges trimmed it is placed in a milling machine where it is bored to a specified size.

cost of fuel used at the Roanoke shops was considerably below the average, since the hauling was done by the Norfolk & Western. Oil was delivered at Norfolk via ships at approximately three cents a gallon. The power consumption has been figured conservatively, so that the actual consumption will be within 10 % of the figures shown, plus or minus. However, neither the cost of fuel nor the cost of power are deciding factors, and should not be treated with too much importance. Equal attention should be given to other important items entering into the costs analysis.

The maintenance cost on the electric furnaces and oven since installation has been practically nothing, with the result that further savings may reasonably be expected in addition to those outlined in detail. The cost of electric power, whether it be for motors, electric lights, electric ovens or furnaces, becomes a secondary matter when due consideration is given to the results.

One may well inquire as to the reason why electric heating produces such results in comparison with fuel-fired equipment.

Suppose it is desired to anneal castings at 1 650° F. For best results the temperature of the castings should not vary from normal more than 25°. If fuel is used, it is necessary to start with heat generated probably at as many as eight points with a flame temperature of about 3 000° F. A thermocouple is placed within the furnace, care being taken to see that it is not set in the path of the flame. The temperature at that point is called the temperature of the furnace. While this may be the temperature of part of the charge, some parts of the charge will be subjected to the direct radiation of the flame or to on incandescent wall on which the flame is impinging, while other parts will be entirely out of reach of such radiation, and even out of reach of any convection currents. It is not at all difficult to imagine the conditions of heating which will result.

Summary of power costs and savings effected by the use of electric heat at Roanoke shops of the Norfolk and Western.

Application.	*Power cost per year.*	*Total savings per year.*
Babbitting of bearing.	$1 824	$17 400
Armature and coil baking	864	17 472
Tool heat-treating.	600	6 854
Carburizing	1 413	18 720
Core baking	5 760	11 376
Annealing steel castings.	7 344	30 222
Grand totals.	$17 805	$102 044

In comparison with this, where a temperature of 1 650° F. is required for the heat-treatment of castings, suppose the heat were generated, not from eight points, but from an infinite numbers of points, and that the maximum temperature is limited to 1 700° F. instead of 3 000° F. Suppose the heating elements are placed within this furnace chamber in such a manner as to compensate for all door losses and other naturally cold areas within the furnace chamber, and in addition, liberate heat uniformly to the charge. The result is that the furnace atmosphere at every point is at the same temperature, and the entire charge will gradually come up to the temperature of the controlling thermocouple, or 1 650° F., no more, no less.

If time had permitted, many other items of direct saving could have been investigated and brought to light. Deducting the entire cost of electric heating at the Roanoke shops from the savings as recorded, a net minimum saving of $84 139 a years is shown.

CURRENT PRACTICE.

[625 .232 (.42)]

New third class sleeping cars, London and North Eastern Railway.

Figs. 1 to 3, p 886 and 887.

The popularity of the third class sleeping car which was first introduced in the Autumn of 1928 has necessitated further additions to the existing stock.

Previous vehicles have been of the convertible type and could be used as ordinary corridor third class carriages if required, but the ten new sleeping cars which have recently been constructed at the Company's York works, to the design of Mr. H. N. Gresley, the Chief Mechanical Engineer, are not convertible and will be used on trains in which there is a constant demand for sleeping accommodation.

These cars, which are 9 ft. 3 in. wide, are 66 ft. 6 in. long over body and being 5 feet longer than the previous vehicles, provide berths for 32 passengers as compared with 28 in the earlier cars.

The body is built of teak and special insulation has been provided to minimise noise, the spaces in the floor, sides and roof being packed with Limpet asbestos felt. Indiarubber body pads are also fitted between the body and the underframe.

The underframe is built entirely of steel and is mounted on two bogies of the latest L. N. E. R. compound bolster type having special bolster springs to ensure smooth running. Buckeye auto-

Fig. 1.

Fig. 2.

Fig. 3.

matic couplers and Pullman vestibules and vacuum brake are fitted in accordance with the standard L. N. E. R. practice.

The fact that the compartments are not convertible has enabled many improvements to be introduced. The compartments are panelled throughout in teak, each compartment being now provided with only one window in the body side and none on the corridor side, thus ensuring a greater degree of privacy.

The fixed berths are provided with « Vito » mattresses upholstered in blue and fawn moquette. To facilitate access to the upper berths a small fixed ladder with platform is provided near the window, the platform forming a small table.

Each compartment is also provided with a large mirror on the sliding door together with the usual complement of luggage racks, hat and coat hooks, etc., further luggage accommodation being provided by means of a shelf formed by roofing over the corridor.

Special attention has been given to the lighting and ventilation. A three-light roof fitting is fitted in each berth, two lamps providing the general lighting, the third being a blue lamp which automatically acts as a night light when the others are switched off. In addition a special enclosed reading lamp is provided at the head of each berth. The electric lighting equipment is of the Stone's double battery type. Ample ventilation is ensured by two torpedo ventilators fitted in the roof of each berth and a glass louvre ventilator at each window, the window being made to drop. A small louvre ventilator is also fitted in the corridor partition at the head of each berth.

The vehicles are fitted with steam heating throughout, a special feature being that heaters are provided in the corridors as well as in the berths.

Separate lavatory and toilet compartments are provided at each end of the vehicle. The wash basin is of large size and is supplied with hot and cold water. A drinking water filter is also fitted together with « Dixie » cup dispenser in order that each passenger may be provided with a clean cup.

The exteriors of the vehicles are finished in natural varnished teak and lettered « Sleeping Car ».

[62 .01]

Radiography applied to railway materials,

by HERBERT R. ISENBURGER (1).

Figs. 1 to 8, pp. 890 to 895.

(*Railway Mechanical Engineer.*)

Non destructive routine testing of critical structures has become of foremost importance. One of the most reliable methods is the radiographic examination. Thereby, shadow-pictures are obtained of the interior condition of the object under investigation without destroying or in any way harming it. The means by which these pictures are made is a penetrating radiation of either X-rays or gamma-rays. The first kind of radiation is produced by electrical current through an X-ray tube; the latter rays which are of shorter wave length than X-rays are obtained from radium or its emanation.

A diagram of the radiographic arrangement is shown in figure 2. The focal spot *A* which is either the target of an X-ray tube or the bulb containing the radium, should be as small as possible in order to obtain sufficiently fine detail in the film *F*. When using X-radiation a heavy lead shielding *L* around the film holder *H* is essential in order protect the negative from being fogged by secondary or scattered rays.

As with ordinary photographs, darker regions on the negative or lighter regions on the print mean that more rays have passed through the object at that point which indicates that the object is more transparent there. Hence cavities will show up in the prints as light spots whereas heavy impurities or more dense metal will appear darker.

The absorption of the rays grows with the atomic weight of the material examined. It is almost proportional to the third power of the atomic numbers and weights, which are shown in the following table :

Element.	Atomic number.	Atomic weight.
N	7	14.00
O	8	16.00
Mg	12	24.32
Al	13	26.97
Fe	26	55.84
Cu	29	63.57
Zn	30	65.38
Mo	42	96.00
Sn	50	118.70
W	74	184.00
Pb	82	207.20

On account of its heavy atomic weight, lead is used to protect the operator, since sufficient thicknesses of lead will absorb the rays completely.

Railroad applications of X-ray inspection.

There are two particular fields in the railway industry where radiographic inspection is of utmost value : foundry and welding practice. In foundry practice there are two important applications of metal radiography. One of these concerns

(1) Mr. Isenburger is secretary and treasurer of the St. John X-Ray Service Corporation, 505, Fifth avenue, New York.

Fig. 1. — Industrial installation of portable X-ray equipment.

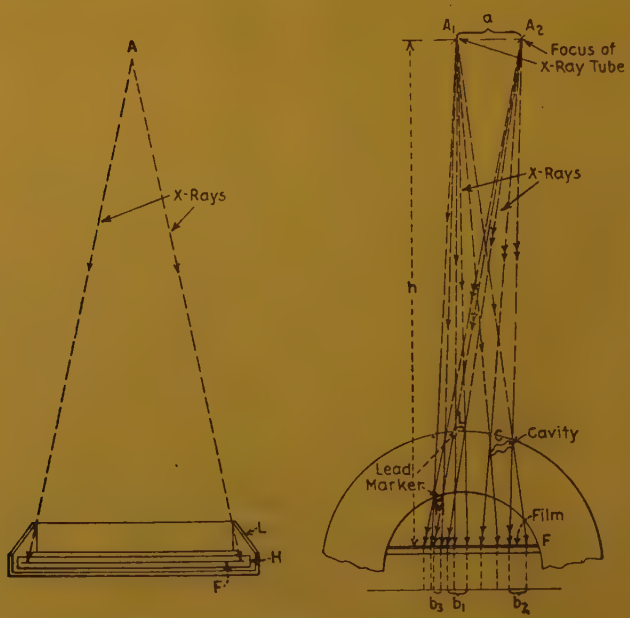


Fig. 2. — Left : Diagram of radiographic arrangement. — Right : Diagram showing location of sand pocket revealed in photograph, figure 3.

the development of manufacturing technique, the other the final inspection of the finished product. Although this method seems expensive, there are many cases where the possible failure of a casting or forging would cause damage far in excess of the cost of the examination. Here radiographic inspection becomes a matter of insurance.

X-ray tests confirmed by cutting a section of the casting and by other

Fig. 3. — Large sand pocket in 2 1/2-inch cast steel.

means of examination indicate that the undesirable internal conditions in castings fall into relatively few classes, all of which are traceable to definite and simple causes. Most of these causes, if not all of them, can be eliminated by proper foundry practice. Experience shows that when defects have been corrected by making the required changes in foundry methods they tend to stay corrected. It is thus possible, by the aid of radiography and the conclusions drawn from its results, to eliminate from 75 to 90 % of the more important defects in castings produced by a given foundry.

Conditions found in steel castings.

The principal undesirable conditions in steel castings revealed by radiographic examination are the following :

1. Gas, slag and land pockets due to loose dirt in the mold.

2. Gas cavities due to imperfectly deoxidized metal.

3. Sand inclusions due to cutting of the mold or runners. Figure 3 depicts a large sand pocket in a section of cast steel 2 1/2 inches thick. In order to

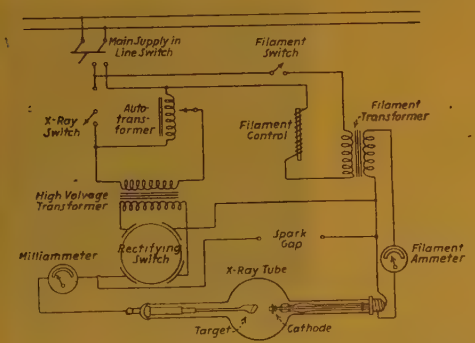


Fig. 4. — Wiring diagram of a typical installation for generating X-rays.

determine the depth and location inside the wall two exposures have been made on the same film as schematically shown the drawing, figure 2. Lead markers L and M were placed on the outer and inner surface of the castings. Before taking the second picture the source of radiation A was moved in any one rectilinear direction at a predetermined distance $A_1A_2 = a$. The distance h between focus and film was also predetermined. The film then records two images of the same cavity C and markers, L and M. The respective displacements can be measured on the film; they may be b_1, b_2 and b_3 inches. Referring to the

photograph, the shadows of the reference marks on the outer surface were displaced 9/16 inch or more; and the small marker on the inner surface 3/8 inch. In the same way displacements of various spots in the sand pocket have been measured. It was thus determined that the inclusion lies just under the outer surface and does not penetrate more than one quarter through the wall; hence it does not cause any serious defect, and an expensive casting which would have been rejected was saved. This particular casting weighed over three tons.

4. Pipe or primary shrinkage caused by failure of the risers to function as indicated.

5. Secondary pipes caused by flow of viscous metal through constricted channels in the casting during the final stages of solidification.

6. Shrinkage cracks starting from a sinus-like cavity developed during cooling.

7. Rupture developed during pressure test. Figure 5 shows a portion of a steel casting which was selected by the customer's inspector as particularly good, after applying ordinary inspection tests. The radiograph revealed a

Fig. 5. — Portion of steel casting passed by the customer's inspector as being particularly good.

sharply defined crack starting from a small cavity or inclusion. Its location was marked with crayon on the outside of the casting, and it was found where indicated when the piece was sectioned. Moreover, micrographic examination of the material adjacent to the crack showed that it had been cold-worked. The casting was probably ruined in the very test that proved it « good ».

The marked progress in locomotive design and other lines of railway activities present increasingly numerous cases where such tests may be applied and where they often will be found absolutely necessary. While these conditions are perhaps more prevalent in the case of castings, they also occur with forgings as well as bar or plate stock.

X-rays should be employed whenever advisable on steel castings and forgings having a tickness of 3 inches and less, whereas gamma-rays should be used for the examination of heavier material; 12 inches of steel have been sucessfully penetrated thus far. For radiographic inspection of welded seams, X-rays should be used whenever possible, since this kind of radiation gives more detail in the picture than gamma-rays. The appearance of the various defects is almost the same whether in castings or welded seams, but the precision in X-ray examination can be raised up to one per

cent in 1-inch stock and less, or up to 2 % in 3-inch stock and less; but to not better than 5 % in gamma-ray examination; this holds good for blow holes which lie in the direction of the rays.

The location of a defect within the weld metal can be determined in a manner similar to that described, or can be calculated from the following proportion :

$$a \cdot b = (h - x) : x$$

wherein x is the unknown distance between the defect and the film; the film being placed close to the object. In many cases this way is preferable in weld inspection where the defect is mostly a very small spot; b is the displacement of this defect.

Figure 6 depicts a weld in 1 1/8-inch stock. In this radiograph three differently dense regions appear : region *A* represents the plate, region *B* the built-up metal on the surface toward the X-ray tube, and region *C* which contains the actual weld and shows the built-up metal on the side facing the film. Although this is a porous weld it may be considered permissible for the service intended. Here lies the danger of radiographic tests of welded seams : that the picture may show an apparently bad condition

Fig. 6. — Radiograph showing weld in 1 1/8-inch stock.

which actually is permissible. In this respect X-ray inspection tends to be a rigid test, calling for skill in the interpretation of the film combined with thorough knowledge of the material's ultimate use. Its results have to be studied carefully and whenever possible, expert advice should be obtained. For certain purposes, of course, welds, as shown in the picture of the 2-inch plate stock, figure 7-1, are preferable. That they can be made and are being produced frequently has been proved by the X-ray.

The X-ray pictures, figure 8, show electric arc-welded test plates from 5/8-inch stock made by the same welder : The top view as originally submitted for X-ray examination; and the lower view made after a thorough study of the X-ray evidence which revealed that the soundness of a weld depends not only on the answers to the preceding questions, but also on the quality of the rod and its coating, the way the welder holds the arc and the speed by which the joints are being fused together.

All welds illustrated thus far were made with the electric arc. It is equally important to inspect gas welds. Figure 7-4 depicts an acetylene weld which is rather good. Notice the built-up metal over the bottom of the V in contrast to the two X-ray pictures referred to in the preceding paragraph which represents

the type of weld used for joining small size tubings which cannot be welded from the inside.

The following questions concerning welding can be answered with X-ray pictures :

Is a weld sound throughout ?

Are there any inclusions of gases, slags, sand or other impurities ?

Was there any undesired absorption of gas ?

Is the welding rod of the proper size and was the current density appropriate ?

Is a weld burned ?

How did the fusion turn out (thorough penetration) ?

Did any cracks develop within the welded section or the neighboring region and what causes such shrinkage ?

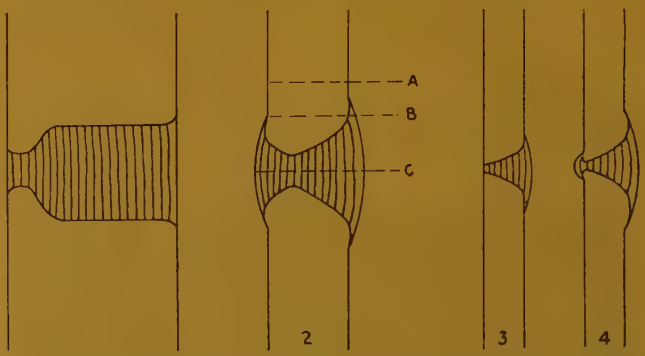


Fig. 7. — 1 : Sketch showing radiograph of a sound we'd in 2-inch plate stock ; 2 : Sketch of weld from radiograph shown above ; 3 : Weld shown in illustration of test plates from 5/8-inch stock (fig. 8) ; 4 : Sketch of a good gas weld.

Are there any thinner spots within the weld metal caused by improper welding procedure ?

Were there any repairs made afterwards, like caulking copper welds ?

In this way, not only can the welding process be improved, but work can be controlled and bettered.

Comparatively little radiographic work has been done in the railway industry in the U. S. A. whereas the German State Railways use it to considerable advantage. The management has an elaborate X-ray laboratory in its machine shops at Wittenberge near Berlin and also equipment mounted on cars with living quarters for the operator that can be sent any place where it is desired to inspect material.

The cost of suitable X-ray installations and their operating expense depend a great deal on the materials to be examined. The figures given below can therefore only be approximate estimates for average performances and requirements. The type of installation to be used for various inspection work depends largely upon the nature of the material, its thickness, conditions and mobility. A conservative estimate of operating cost is $3.00 to $5.00 per hour, depending on the way the equipment is written off. The cost of radiographic inspection by means of gamma-rays is difficult to estimate. The radio-active material can be rented for a certain time and in most cases the expense for such work equals the cost when X-rays are used. There are certain cases where it is easier to bring the radium to the job than X-ray equipment although the thickness of the material may be within the X-ray limits.

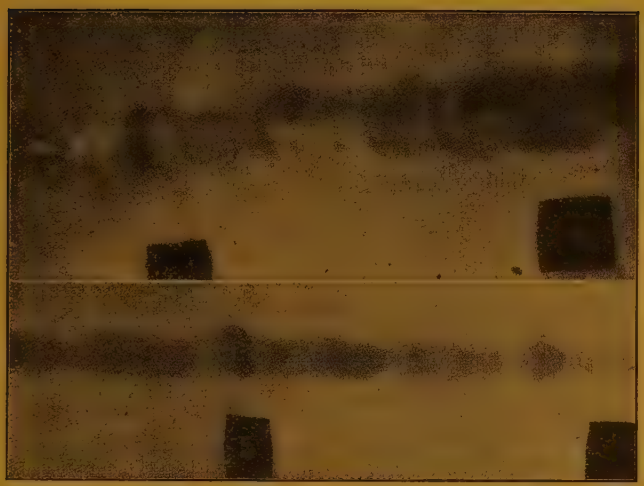


Fig. 8. — Electric arc-welded plates from 5/8-inch stock. (See fig. 3.)

X-rays should, however, be employed whenever possible, since they bring out better contrast and more details in a much shorter exposure time.

X-ray equipment, however, should not be installed until the adaptability of the method to the problems in hand has been demonstrated, and not then unless the benefits to be derived justify the investment. This would seem to make the tool unavailable to the organization with a small problem or a temporary difficulty.

MISCELLANEOUS INFORMATION.

[621.136 (.73)]

Pennsylvania Railroad experimental tender.

Fig. 1, p. 896.

(*Modern Transport.*)

The Pennsylvania Railroad, as briefly recorded in the 23 May issue of *Modern Transport*, has recently equipped one of its Class K. 4 *Pacific* type passenger engines with a tender of exceptional dimensions, which vehicle is shown in the accompanying illustration. The tender — for particulars of which we are indebted to Mr. F. W. Hankins, assistant vice-president of operation, Pennsylvania Railroad — is of entirely new design and has been built experimentally with a view to increasing the length of locomotive runs and eliminating delays due to stopping for coal and water. It has a water capacity of 24 410 gallons (U.S.) — or 20 342 gallons in British measure — and there is space for 50 240 lb., or nearly 22 1/2 tons, of coal. The tender is fitted with a water scoop in accordance with Pennsylvania Railroad practice, but the chief object of the huge tank provided is the eventual elimination of water stations and, in consequence, a reduction in operating expenses. As may be seen from the illustration, the tender is equipped with two six wheeled bogies, the diameter of the wheels being 2 ft. 9 in. The overall length, measured over the rear coupler face, is 55 ft. 5 1/4 in., while the bogie wheelbase is 9 feet and the length between centres of bogies 31 feet. The overall length of engine and tender, measured over the front and rear coupler faces, is 104 ft. 9 1/2 in. The weight of the tender empty is 142 180 lb., or about 63 tons 10 cwt., while the weight loaded is 395 835 lb., or approximately 176 tons 15 cwt.

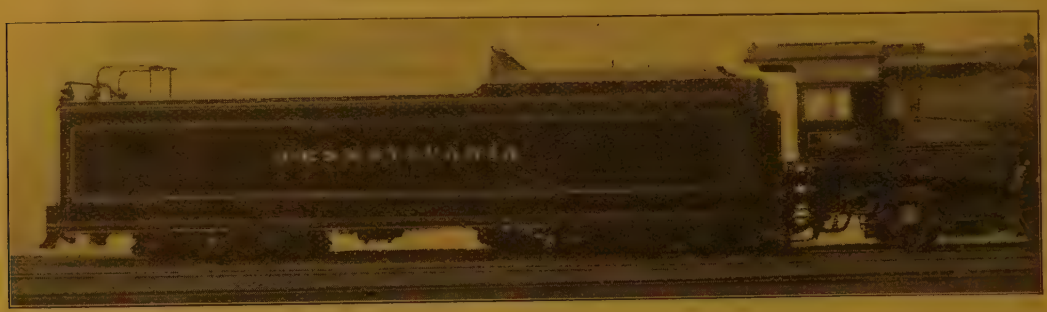


Fig. 1.

Comparative weights and capacity.

As to comparisons with conventional practice, it may be mentioned that the Class K. 4 locomotives of the Pennsylvania Railroad are equipped with standard tenders of 7 850 gallons (U. S.) — about 6 542 gallons in British measure — carrying 13 tons of fuel, their

weight empty being 78 800 lb., or about 35 tons, and loaded 171 400 lb., or about 76 tons 10 cwt. Thus, by comparison, the new tender has 16 560 gallons (U. S.) — 13 800 gallons in British measure — greater water capacity, while for fuel the increase is 9 tons 10 cwt. The increase in the light and loaded weights of the new tender is 28 tons 10 cwt. and 100 tons respectively. The loaded weight of the experimental tender may also be compared with that of the engine, which has a weight in working order of 139 tons 5 cwt., as against that of 176 tons 5 cwt. for the tender, or an increase of 27 %. Incidentally, the Class K 4. *Pacific* locomotives have cylinders measuring 27 inches by 28 inches, a working steam pressure of 205 lb. per sq. in., and driving wheels of a diameter of 6 ft. 8 in. The total combined heating surface is 4 984 sq. feet, and the grate area 70 sq. feet. At 85 %, the rated tractive effort is 44 470 lb., while the total weight of the engine and the large tender is 316 tons 10 cwt.

[625 .144.4 & 625 .17]

Shovel packing.

(*The Railway Engineer.*)

The search for improved rail joints, and for the reduction of their number by the use of long rails, is based not only on grounds of economy but at least equally on the assumption that it is chiefly the joints between rails which prevent the perfectly smooth passage of trains over the track. Those with an intimate experience of permanent way maintenance know, however, that it is much less the rail joints which contribute to rough running, than the failure to keep an exactly even top to the rails, not only at joints but between them, level on the straight and regularly canted for the agreed speed on curves. There is no difficulty in setting the road correctly, but the effect of moving loads soon makes itself apparent by disturbing the ballast and, if the ballast is in any way deficient, or the drainage faulty, the formation also. The irregularities thus set up are dealt with, under the system of maintenance in force in this country, as they arise, by either packing the existing ballast tightly under loose or low sleepers, or by adding fresh ballast without disturbing that which has already become consolidated. The former method is known as beater packing, and the latter, which is fast gaining popularity, as shovel packing.

Shovel packing consists in lifting the track, under one rail at a time, high enough to allow of the spreading under the sleeper of enough fine ballast (1/4-inch stone chippings or crushed gravel) to adjust the rail level. The ganger observes and marks any low places in the rails, and, in addition, places which, though not apparently low become so under load. This having been done over a length of perhaps a quarter of a mile, the ballast between the sleepers concerned is thrown out (to avoid the risk of any loose stones rolling under the sleepers when they are lifted), the track under the rail, the level of which is to be adjusted, is raised 2 or 3 inches by means of a jack, or a bar and fulcrum, and the fine ballast evenly spread for a width of about 2 feet under the rail, by means of a small shovel. The necessary quantity having been thus inserted, the track is dropped again, and, if the amount has been correctly judged by the ganger, the true level will be found to have been restored after the passage of the next train has consolidated the added ballast.

The main advantages over beater packing of this method of maintaining the track are that if can, after a little practice, be done more quickly and with less expenditure of energy;

the placing of the additional ballast being undertaken always by the same man, as a rule the ganger, the results are more regular than when several men are engaged on beating up, since no two men put exactly the same amount of force into their work; the old ballast is not disturbed and so weakened, but is re-inforced by the addition of new; and the repair of beaters is eliminated.

The method described was in force on the old London & North Western for many years, and is, we believe, now universal throughout the London Midland & Scottish system. It is also practised on the London & North Eastern and the Southern, and several Continental lines have recently adopted it. With experience remarkably good results have been achieved, and the platelayers who have successfully mastered the method are enthusiastic in its praise.

NEW BOOKS AND PUBLICATIONS.

[385. 09 (.6)]

WIENER (L.) Professor at the free University of Brussels. — **Les chemins de fer coloniaux de l'Afrique. (The African Colonial Railways).** — One volume (9 1/2 × 6 1/2 inches) of 574 pages, with 31 figures (maps). — 1931, Brussels, Goemaere, publisher, rue de la Limite, 21 ; Paris, Dunod, publisher, 92, rue Bonaparte. (Price : 75 francs).

The important part played by the railway in the development of new countries is well known. Even better than water routes which it is often impossible to use directly, they make it possible to reach the mining or agricultural regions and bring them the machinery and manufactured goods of the mother-country, and also to carry back the produce of the soil or mines to the coast. Until the time, often far off, when the progress of civilisation will have brought with it the creation of large industrial or commercial cities, they will retain the characteristics of penetration railways. This is the case with the African railways which all start from the coast and do not yet reach very far inland with a few exceptions, such as the lines in French North Africa, the South African Railways and two lines which converge towards the Belgian Congo, one from the Cape running northwards and the other from Alexandria up the Nile valley.

In addition to commercial interests, in Africa a political motive, the need to consolidate the influence of the colonising European countries, still plays a part in determining the construction of railways; lines of occupation have sometimes preceded agricultural and mining lines.

Furthermore, as time goes on and the continent gradually reveals its riches, the railways will penetrate deeper into the country and the object of projects known under the name of lines of access is to reach vast interior regions of great economic possibilities.

M. Wiener's book is a very complete study of the African railways, in the sense that it includes all the lines of all the existing railways without neglecting distant possibilities of development or great projects; it deals with all the railways of the French colonies and protectorates, those of the Portuguese possessions, the lines of the English possessions and those of the Belgian Congo.

It is also complete in the sense that for each line or railway system, it gives a monograph starting with the first investigations and ending up with the present situation by describing the whole material and economic development.

In a methodical way, the author describes the legal position of the lines, which frequently reflect the political organisation of the country, and the financing of the enterprises which is often faced with great difficulties. The most interesting pages are those depicting the efforts made to overcome the many obstacles met with in colonial countries : scarcity of labour, bad climate, lack of local ressources, slow and difficult bringing up of material. Well-deserved tribute is paid in passing to the pioneers who traced out these lines of civilisation through such perils. Technical and economic questions are all dealt with in their proper places, and the reader is thus enabled to appreciate the effects they had on each other. The reasons which led to the choice of such and such a gauge are seen and likewise the consequences of the limiting gradients and curves adopted.

When dealing with the superstructure of the track and the types of rolling stock interesting observations are made on their relative effect as regards the traffic and the statistics given show the great possibilities of the narrow gauge track predominating on the colonial railways. The analyse ends with a report of the services rendered by these undertakings. Numerous statistics indicate the nature, importance and the development of the traffic, the working results and the financial results.

Maps showing the existing and projected lines help to make their objective more precise. They add an element of appreciable value to the profuse and well arranged collection of information given.

E. M.

[347. 762 (.493)]

STEVENS (E.), Advocate of the Brussels Court of Appeal, Legal Adviser of the Belgian National Railway Company, and HENNING (R.), Chief Inspector of the Belgian National Railway Company, Professor at the Mons Commercial and Consular Higher School. — **Le Contrat de Transport**. Première partie : **Le Contrat de Transport en Belgique.** (**Transports Contracts**. Part one : **Transports Contracts in Belgium**). — One volume (10 × 6 1/2 inches) of 752 pages. — 1931, Brussels, Imprimerie Lesigne (S. A.), publisher, 27, rue de la Charité. (Price : 115 Belgian francs).

Every day hundreds and hundreds of transport contracts are made. The passenger who takes a ticket at the booking-office, the tradesman who sends off a parcel, are each making a transport contract with the railway. But what are the conditions? Where are the announcements to be found? What is the exact object of the contract? Where do the obligations of the carrier end and how extensive are they? All these are essential questions which the railway client rarely asks himself in the first place but which are at once raised in case of dispute. It might be a matter for astonishment that to answer them completely and exactly requires a large volume of 752 pages. But transport contracts can exist under very different forms according to the nature of the object transported and because of the numerous tariff measures that exist. In the course of carrying out the transport and even afterwards, all sorts of incidents can occur which impede the regular progress of the goods or render them liable to damage.

The matter is abundant. Based upon their great experience following a defined method, the authors have written a remarkable treatise which is at the same time a manual of law.

The subject is not confined to special legislation regarding transport. Many questions of ordinary law can crop up during transport. Like all things of value, goods handed over to the railway can give rise to covetousness, and result in claims being made; usually the change in place is accompagnied by a change in ownership. The total or partial loss of the goods, or its late arrival may involve the interests of a third party. Following step by step the carrying out of the transport contract the authors have wished to deal with every case that their daily practice had shown them to be of interest by indicating and discussing the lessons taught by theory and law.

The work deals with transport of goods as well as of passengers and luggage. The question of responsibility is examined both in the case of the single carrier and when the transport involves several carriers in turn. Finally legislation concerning modern transport by mo-

tor vehicles on the roads and by air is subjected to a special analyse.

To whom will the study of this book be profitable? The railway, a public service, considered as holding a monopoly, bears the weight of heavy obligations and responsibilities. Nothing is more legitimate for those who have to watch over its interests or to defend them than to take care to limit its burdens so far as the existing laws allow. Its officials and legal advisers will find in this didactic treatise a valuable guide. As the report is impartial and to the point, it can also instruct the great number who use transport. To enlighten everyone as to his rights and his obligations and on the way of consolidating the one and fulfilling the other is an efficacious way of facilitating and improving the relations between the carrier and his clientel.

E. M.

[621 .13 (02. 621 .33 (02. 625 .2 (02 & 656 .23 (02]

CORINI (Felice), Doctor of Engineering, Professor at the Bologna Royal School of Engineering. **Costruzione ed esercizio delle ferrovie (Construction and operation of railways).** — *Third volume* : **Trazione termica e materiale mobile (Thermic Motor Traction and Rolling Stock)**, 2nd edition. — One volume (9 1/2 × 6 3/4 inches) of 542 pages, with 9 plates and 443 figures. — *Fourth volume* : **Trazione elettrica e ferrovie speciali (Electric Traction and special Railways)**, 2nd edition. — One volume (9 1/2 × 6 3/4 inches) of 538 pages, with 5 plates and 471 figures. — *Fifth volume* : **Movimento e traffico e questioni economiche (Operation, Traffic and Economic Questions)**, 2nd edition. — One volume (9 1/2 × 6 3/4 inches), of 135 pages, with 1 plate and 17 figures. — 1931, Turin, 116, Unione Tipografico-Editrice Torinese, 28, Corso Raffaello.

These three volumes of the treatise by Mr. Felice Corini are the continuation of those briefly reviewed in the December 1929, and September 1931, numbers of the *Bulletin*, and which were entitled, the first, *Meccanicà della Locomozione* (The Mechanics of Locomotion), the second, *Costruzione ed esercizio delle ferrovie. — Impianti. The Construction and Operation of Railway Lines. — Fixed plant)*.

The third volume deals with the steam locomotive of both the piston and the turbine types, and the internal combustion motor locomotive, with the various types of transmission, excluding, however, electric transmission which is reserved for the fourth volume.

The first chapter deals with piston locomotives from both the thermic and the mechanical points of view. It describes the apparatus and the methods used for measuring the work done by them.

The second chapter which deals with the turbine locomotive discusses the reasons for which this form of traction may be adopted, gives particulars of the types of turbines used and sets out the theory as well as the characteristic features of the turbine locomotive. It describes the turbines built, the transmission gears and the equipment necessitated by condensing.

The third chapter gives the calculations for the Diesel motor together with the leading characterictics of the locomotive when fitted with a motor of this kind and deals very fully, and with reason, with the transmission question, the most difficult to solve.

The fourth chapter considers the locomotive as a vehicle; the fifth describes the construction and working of the boiler and its fittings and takes particular interest in the high-pressure boilers recently tested.

In the fifth chapter, the author gives

the leading dimensions of a series of piston and turbine locomotives with, in some cases, diagrams or full drawings.

The two last chapters deal with the rolling stock, and the brakes.

The application of the continuous brake to goods trains has received the attention which this recent progress deserves.

The fourth volume includes two parts relating to electric traction : the equipment of the line and the rolling stock; a third part deals with special railways (rack, funicular, telfer).

The first chapter deals with the evolution and the development of electric traction.

The second describes the production and transformation of electric energy in steam and hydraulic power stations, lays particular stress upon what characterises the feeding of a traction system. The sub-stations are dealt with for the different systems : low frequency and industrial frequency, three-phase, single-phase, and continuous. A paragraph describes automatic sub-stations.

The third chapter discusses with all the necessary theoretical developments and with all usefull indications of construction methods, the question of the feeder lines and the contact wires.

The second part consists of five chapters, the object of which can be defined as follows :

1. theoretical study of the traction motor;

2. electric braking and regeneration of energy;

3. construction features of traction motors and transmission gears;

4. electrical control apparatus, auxiliaries and current collectors;

5. method of designing an electric locomotive, and description of a certain number of existing locomotives. This second part has many figures together with many plates at the end of the text.

The third part describes the classification and the essential considerations in connection with rack railways, funicular railways, and telfer railways, investigates the limiting conditions of application, and the arrangements adopted for the essential apparatus. The question of safety (engagement of the gears with the rack, brakes, strength of cables) is discussed with the necessary fulness.

The fifth volume, although having fewer pages than the others, deals however with questions of equal importance.

The first chapter deals with the form of operation of the railways (private companies, State operation) ; it examines the effect of the system upon the development of railways in Italy.

The second chapter considers how the time tables should be drawn up to meet the needs of the users, and the requirements of the service, how the running time between stations should be fixed, and how the time tables should be presented.

The third chapter analyses the operating regulations, the methods followed to regularise the movements of the trains, and to get satisfactory use from the rolling stock.

The fourth chapter discusses the general economic principles which should dominate the operation, the bases and the objects of the rates system, the relationship between the rates and the costs and the methods of calculating the latter.

The fifth chapter deals with legislation as affecting railways, their administrative organisation, and the essential requirements of the transport contract.

The sixth and last chapter deals with the financial regime of the railways, with the manner of analysing the results according to certain index numbers, and with the limits of application of electric traction, and makes a short comparison between railways and other methods of transportation.

E. M.

[385 (06.111]

OFFICIAL INFORMATION

ISSUED BY THE

PERMANENT COMMISSION

of the International Railway Congress Association.

Meeting of the Permanent Commission held on the 25 July 1931.

The Permanent Commission of the International Railway Congress Association met on the 25 July last at the Headquarters' Offices of the Belgian National Railway Company at Brussels, Mr. E. Foulon being in the chair.

* * *

The Meeting sanctioned the appointment of the following new members of the Permanent Commission :

Mr. Dantschoff, Ingénieur, Directeur des constructions des Chemins de fer de l'Etat, Bulgaria (new mandate allotted according to the decision taken by the Permanent Commission at the Meeting held on the 18 October 1930) ;

Mr. P. A. Clews, European Traffic Manager, Canadian National Railways, London;

Sir George McLaren Brown, K. B. E., European General Manager, Canadian Pacific Railway, London;

the latter two new mandates were also allotted at the Meeting of the 18 October 1930.

Furthermore, Messrs.

Ching Chun Wang, Director, Chinese Government Railway Material Purchasing Commission, London, and

van Marle, Inspecteur Général des Chemins de fer et Tramways néerlandais, The Hague,

were elected members of the Permanent Commission in place of Messrs. Tsang-Ou and Stieltjes respectively, who had resigned as the result of a change in their official position.

On the other hand, on the proposal of five members and as the result of a written vote taken in conformity with article 6 of the Rules and Regulations, Mr. Oddone, Directeur Général des Chemins de fer de l'Etat, Italy, who has retired, is maintained as member of the Permanent Commission until the Cairo Congress, in 1933.

Finally, the members of the Executive Committee of the Egyptian Local Organising Commission of the 1933 Congress, were elected temporary members of the Permanent Commission, namely :

The General Manager of the Egyptian State Railways;

H. E. Joseph Aslan Cattaui Pacha;

Henri Naus Bey;
Mahmoud Chaker Bey;
Dr. I. Levi;
Youssef Bey Risgallah;
Fouad Bey Hassib.

The meeting then examined the principal arrangements to be made for the organisation of the 12th Session. It was decided that the sectional meetings might take place in the 4 large assembly rooms of the buildings of the Society of Political Science and the Institute of Entomology; these buildings will be connected by a temporary pavilion in which the registration rooms, correspondence rooms, cloak rooms, etc., will be located.

The choice of the badge was approved.

The opening meeting of the Congress was provisionally fixed for the 19 January 1933, the closing meeting for the 30 January.

A reception will take place at Alexandria on the 17 January, on the arrival of the delegates in Egypt, and excursions will be organised during and after the Session.

The shipping companies have been approached with a view to obtaining special conditions for the journey of the delegates to Egypt and their return home. It may be expected that important reductions of rates will be granted for the occasion.

It was noted that the preparation of the reports for discussion at the Cairo Session is well in hand and it is hoped these works will all be published in time for their distribution to the delegates before their departure for Egypt.

The statement of receipts and expenses for the financial year 1930 was approved by the Meeting and the examination of the budgets for 1931 and 1932 showed that the financial situation is satisfactory.

It was decided that the present rate of the variable contribution will be maintained for the financial year 1932.

On the other hand, the report of the auditors, whom the Madrid Congress entrusted with the task of checking the accounts of the Association for the period : 1 January 1926 to 31 December 1930 (accounts of the Madrid Session), was read out to the meeting.

This report was ratified and sent to the members of the Permanent Commission together with the accounts relating thereto.

The Meeting also considered the new contract recently gone into with Messrs. Weissenbruch, printers, for the supply of the 3 editions (English, French and German) of the monthly *Bulletin* of the Association.

In accordance with this new contract, the sale of the *Bulletins* is now dealt with by the Secretariat of the Association.

It was also decided that the 2nd, 3rd and 4th pages of the cover of the special issues of the reports to be presented at the Cairo Congress will be devoted to the publication of advertisements.

* * *

The following changes have taken place in the membership of the Association since the last Meeting.

A. — ORGANISATIONS.

The « Premier Groupement des Administrations de chemins de fer régionaux européens faisant partie de l' U. I. C. » has been affiliated.

B. — RAILWAY ADMINISTRATIONS.

Admissions.

	Km.	*Miles.*
Benguela Railway Company.	1 347	837
Jefatura de Explotacion de Ferrocarriles por el Estado (Spanish State Railway)	273	170

Resignations.

Société des tramways à vapeur interprovinciaux de Milan - Bergame - Crémone (being wound up)	136	85
Elgin, Joliet & Eastern Railway (U. S. A.).	340	211

French Dahomey Railway Company [this system, 294 km. (183 miles) in length, has been purchased by the State and incorporated in the Administration of the French West African Railways].

The Railway Congress Association at the present time includes 233 administrations operating 632 211 km. (392 845 miles) of lines.

The number of affiliated organisations is now 10.

P. GHILAIN, *General Secretary.* E. FOULON, *President.*

List of Members of the Permanent Commission

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

(25 July 1931)

President :

E. **Foulon** (1), directeur général de la Société Nationale des chemins de fer belges; rue du Progrès, 74, Brussels.

Vice-Presidents :

C. **Colson** (3), membre de l'Institut, inspecteur général des ponts et chaussées, vice-président honoraire du Conseil d'Etat de France, membre du Conseil supérieur des chemins de fer de France; rue de Laplanche, 2, Paris;

U. **Lamalle** (3), directeur de l'exploitation à la Société Nationale des chemins de fer belges; rue de Louvain, 17, Brussels.

Members of the Executive Committee :

The Right Hon. Sir Evelyn **Cecil** (2), G. B. E., privy councillor, director, Southern Railway (Great Britain); Cadogan Square, 2, London, S. W. 1;

P. E. **Javary** (2), directeur de l'exploitation de la Compagnie du chemin de fer du Nord français; rue de Dunkerque, 18, Paris;

D. **Vickers** (1), director, London, Midland & Scottish Railway; Chapel House, Charles Street, Berkeley Square, London, W. 1;

Ex-presidents of sessions, members ex-officio :

The Right Hon. Viscount **Churchill**, G. C. V. O., chairman, Great Western Railway (Great Britain); Paddington Station, London, W. 2;

J. **Gaytán de Ayala**, ancien président du Conseil des travaux publics d'Espagne; Claudio Coello, 48-2º, Madrid.

Members :

R. H. **Aishton** (1), president, American Railway Association; 30, Vesey Street, New York;

T. A. **Alstrup** (1), directeur général des chemins de fer de l'Etat danois; Solvgade, 40, Copenhagen, K.;

W. W. **Atterbury** (2), president, Pennsylvania Railroad Company; Broad Street Station, Philadelphia, Pa.;

F. **Besser** (2), Ministerialrat, Reichsverkehrsministerium; Wilhelmstrasse, 80, Berlin, W. 8;

F. **Boix** (2), administrateur-directeur de la Compagnie des chemins de fer du Nord de l'Espagne; Estación del Norte, Madrid;

F. **Castello** (3), directeur général des chemins de fer au Ministère des travaux publics de la République Argentine; Buenos-Ayres;

J. **Castiau** (3), secrétaire général du Ministère des Transports de Belgique; rue de la Charité, 25, Brussels;

H. **Caufriez** (2), directeur général de la Société Nationale belge des chemins de fer vicinaux; rue de la Science, 14, Brussels;

The Right Hon. Sir Evelyn **Cecil**, G. B. E., (already named);

D. **Chreplovitch** (3), directeur général des chemins de fer de l'Etat yougoslave; Belgrade;

The Right Hon. Viscount **Churchill**, G. C. V. O., (already named);

P. A. **Clews** (3), European traffic manager. Canadian National Railways; 17-19, Cockspur Street, London S. W. 1;

C. **Colson** (already named);

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(1) Retires at the 12th session.
(2) Retires at the 13th session.
(3) Retires at the 14th session.

R. **da Costa Couvreur** (2), ingénieur en chef de la division de la voie et des travaux de la Direction générale des chemins de fer, membre du Conseil supérieur des chemins de fer du Portugal; Bairros Sociaes, Arco de Cego, Rua A, No. 4, Lisbon;

J. **Dantschoff** (3), ingénieur, directeur des constructions des chemins de fer de l'Etat bulgare; Sofia;

Dautry (1), directeur général des chemins de fer de l'Etat français; 20, rue de Rome, Paris;

A. J. **Day** (1), advisory engineer, Office of the High Commissioner for the Union of South Africa; South Africa House, 73, Strand, London W. C. 2;

Sir Francis **Dent** (1), C. V. O., director, Southern Railway (Great Britain); Dock House, Beaulieu (Hants), England;

Dr. **Dorpmüller** (2), Generaldirektor der Deutschen Reichsbahn-Gesellschaft; 35, Voss-Strasse, Berlin W. 9;

F. **Fiori** (2), ingénieur, administrateur des chemins de fer de l'Etat italien; Villa Patrizi. Rome;

M. **Fontaneilles** (3), inspecteur général des ponts et chaussées, président de la section des chemins de fer au Conseil général des ponts et chaussées de France, président du Conseil de réseau des chemins de fer d'Alsace et de Lorraine; rue de Sèvres, 4, Paris;

E. **Foulon** (already named);

Sir Henry **Fowler** (3), K. B. E., assistant to vice-president (research and development), London Midland & Scottish Railway; Derby;

A. **Frank** (2), ingénieur des ponts et chaussées, directeur au Ministère des Communications de Pologne; Warsaw;

J. **Gaytán de Ayala** (already named);

P. **Ghilain** (3), ingénieur en chef au service du matériel de la Société Nationale des chemins de fer belges; rue du Progrès, 74, Brussels;

A. **Granholm** (3), directeur général des chemins de fer de l'Etat suédois; Stockholm;

H. N. **Gresley** (3), chief mechanical engineer, London & North Eastern Railway; King's Cross Station, London, N. 1;

Grimpret (3), conseiller d'Etat, directeur général des chemins de fer au Ministère des Travaux publics de France; 241, boulevard St-Germain, Paris;

R. J. **Harvey** (1), consulting engineer to the Government of New-Zealand; Victoria Street, 34, Westminster, London, S. W. 1;

Henry-Gréard (1), directeur de la Compagnie du chemin de fer de Paris à Orléans; rue de Londres, 8, Paris;

H. **Hunziker** (2), ingénieur, directeur de la division des chemins de fer du Département fédéral des postes et des chemins de fer suisses; Berne;

Sir Cyril **Hurcomb** (2), K. B. E., C. B., secretary to the Ministry of Transport (Great-Britain); 6, Whitehall Gardens, London, S. W. 1;

A. **Jacques** (2), directeur de la voie à la Société Nationale des chemins de fer belges; rue de Louvain, 17, Brussels;

P. E. **Javary** (already named);

E. **Kejr** (1), ingénieur, conseiller des constructions du département V/1 au Ministère des chemins de fer de Tchécoslovaquie; Prague;

U. **Lamaile** (already named);

L. F. **Loree** (1), president, Delaware & Hudson Railroad; Nassau Street, 32, New York City;

Sir George **McLaren Brown**, K. B. E. (3), European general manager, Canadian Pacific Railway; 62, Charing Cross, London S. W. 1;

A. **Mange** (2), administrateur de la Compagnie du chemin de fer de Paris à Orléans, président du Comité de gérance de l'Union internationale des chemins de fer; rue de la Bienfaisance, 42, Paris;

C. **Marchi** (2), député au parlement italien, président général de la Confederazione nazionale fascista dei trasporti terrestri e della navigazione interna; via Francesco Crispi, 10, Rome;

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(1) Retires at the 12th session.
(2) Retires at the 13th session.
(3) Retires at the 14th session.

M. **Margot** (1), directeur général de la Compagnie des chemins de fer de Paris à Lyon et à la Méditerranée; rue Saint-Lazare, 88, Paris;

A. **Marguerat** (2), directeur des Compagnies de chemins de fer de Viège à Zermatt, Furka-Oberalp, Gornergrat et Schöllenen; Lausanne;

E. **Maristany** (1), marquis d'Argentera, directeur général de la Compagnie des chemins de fer de Madrid à Saragosse et à Alicante; Estación de Atocha, Madrid;

C. **Mereutza** (3), sous-directeur général des chemins de fer roumains; Bucarest;

G. **Molle** (2), secrétaire technique à la Direction générale de la Société Nationale des chemins de fer belges; rue de Louvain, 17, Brussels;

L. **Moralès** (3), vice-président du Conseil supérieur des chemins de fer d'Espagne, président du Conseil d'administration des chemins de fer de l'Ouest de l'Espagne, Estación de las Delicias, Madrid;

C. **Oddone** (1), directeur général honoraire des chemins de fer de l'Etat italien; Rome;

Sir Frederic **Palmer** (1), C. I. E., consulting engineer, Office of the High Commissioner for India; 55, Broadway, Westminster, London, S. W. 1;

J. R. **Paul** (1), directeur de la Compagnie des chemins de fer du Midi français; boulevard Haussmann, 54, Paris (IX^{e});

G. **Philippe** (1), inspecteur général des lignes Nord belges; Liége;

P. **Riboud** (3), directeur de la Compagnie des chemins de fer de l'Est français; rue d'Alsace, 21, Paris;

N. **Rulot** (1), directeur du matériel de la Société Nationale des chemins de fer belges; 17, rue de Louvain, Brussels;

A. **Schrafl** (3), président de la Direction générale des chemins de fer fédéraux suisses; Berne;

Sir Josiah **Stamp** (3), G. B. E., D. Sc., chairman and president of the Executive, London Midland & Scottish Railway; Euston Station, London N. W. 1;

Sir Henry W. **Thornton** (1), K. B. E., chairman and president, Canadian National Railways; Montreal, Que.;

Antonio **Valenciano y Mazerès** (3), inspecteur général des ponts et chaussées, administrateur de la Compagnie des chemins de fer de Madrid à Saragosse et à Alicante; General Oráa, 5-3^{o}, Madrid;

H. **van Manen** (2), directeur des chemins de fer néerlandais; Utrecht;

Th. M. B. **van Marle** (1), inspecteur général des chemins de fer et tramways néerlandais; Koningskade, 25, The Hague;

L. **Velani** (2), directeur général des chemins de fer de l'Etat italien; Rome;

D. **Vickers** (already named);

Ching-Chun **Wang** (3), director, Chinese Government Railway Material Purchasing Commission; 21, Tothill Street, Westminster, London, S. W. 1;

Sir Ralph Lewis **Wedgwood** (2), C. B., C. M. G., chief general manager, London & North Eastern Railway; King's Cross Station, London, N. 1;

D. **Willard** (2), chairman of the Board, American Railway Association; president, Baltimore & Ohio Railroad; Baltimore, Md.;

P. **Wolf** (1), Geheimrat, Direktor der Deutschen Reichsbahn-Gesellschaft und Mitglied des Direktionsausschusses dieser Gesellschaft; Voss-Strasse, 35, Berlin W. 9;

N. **Yumoto** (3), secretary of the Japanese Ministry of Railways and manager of its Berlin Office; Friedrich Ebert-Strasse, 6, Berlin W. 9.

N ...(3) (Germany);
N ...(3) (Germany);
N ...(1) (Germany);
N ...(2) (Australia);
N ...(2) (Brazil);
N ...(3) (Egypt).

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(1) Retires at the 12th session.
(2) Retires at the 13th session
(3) Retires at the 14th session.

Honorary member : Gustav **Behrens**, director, London Midland & Scottish Railway; Chepstow Street, 20, Manchester.

SECRETARY'S OFFICE : rue du Progrès, 74, Brussels.

General secretary : P. **Ghilain** (already named).

Secretary-treasurer : J. **Habran**, directeur d'administration honoraire des Chemins de fer de l'Etat belge;

Assistant secretaries : R. **Desprets**, ingénieur principal à la Société Nationale des Chemins de fer belges;

E. **Minsart**, ingénieur principal à la Société Nationale des Chemins de fer belges;

A. W. **Chantrell**, ingénieur principal à la Société Nationale des Chemins de fer belges.

Egyptian Section of the Permanent Commission.

(Executive Committee of the Local Organising Comittee of the twelfth Session),

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President : The General Manager of the Egyptian State Railways.

Members : H. E. Joseph Aslan **Cattaui** Pacha, sénateur, ancien ministre;

Henri **Naus** Bey, directeur de la Société Générale des Sucreries et de la Raffinerie d'Egypte;

Mahmoud **Chaker** Bey, sous-secrétaire d'Etat au Ministère des Communications.

Secretaries : Dr. I. **Levi**, ci-devant contrôleur de l'Administration de la Statistique;

Youssef Bey **Risgallah**, directeur général-adjoint des chemins de fer de l'Etat égyptien;

Fouad Bey **Hassib**, secrétaire général-adjoint de la présidence du Conseil des Ministres.